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# **Manual for Profile Measurement: Operational Field Guidelines**

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## **Abstract**

This manual describes procedures to be followed when measuring pavement profiles for the LTPP program using the K.J Law Profilometer, Face Technologies Dipstick, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping, and maintenance of equipment for each of the profiling methods are described.

## Executive Summary

The Long-Term Pavement Performance (LTPP) program is a study of pavement performance at about 1,000 in-service pavement sections. The objectives of LTPP are to:

- evaluate existing design methods;
- develop improved design methods and strategies for the rehabilitation of existing pavements;
- develop improved design equations for new and reconstructed pavements;
- determine the effects on pavement distress and performance of loading, environment, material properties and variability, construction quality, and maintenance levels;
- determine the effects of specific design features on pavement performance; and
- establish a national long-term pavement performance data base.

LTPP will collect data on in-service pavement sections for a twenty year period. The data collected at the test sections are stored in the LTPP Information Management System data base. This data will be used develop improved pavement design procedures that will enable highway engineers to tailor designs and maintenance to specific conditions.

The annual collection of longitudinal profile data of each test section is a major task of LTPP. The left and right wheel path profile data for five repeat runs on a test section are stored in the data base. In addition, the International Roughness Index (IRI), Mays Index, Root Mean Square Vertical Acceleration (RMSVA) and slope variance, which are computed from the profile data, are stored in the data base.

This manual describes procedures to be followed when measuring pavement profiles for LTPP using the K.J. Law Profilometer, Face Technologies Dipstick and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping and maintenance of equipment for each of the profiling methods is described. The primary device used to obtain pavement profile measurements for LTPP is K.J. Law Profilometer. However, when a Profilometer is not available the Dipstick is used to collect profile data. A rod and level can also be used to measure pavement profiles if a Profilometer or a Dipstick is not available.

# **1. Introduction**

## **1.1 Overview of SHRP and the LTPP Program**

The Strategic Highway Research Program's (SHRP) Long Term Pavement Performance Program (LTPP) is study of pavement performance in different climates and soil conditions at about one thousand in-service pavement sections in all fifty states of the United States and in participating provinces in Canada.

For purposes of pavement data collection and coordination, the U.S. and participating Canadian provinces have been subdivided into four regions, each served by a Regional Coordination Office Contractor (RCOC). The regional boundaries defining the jurisdiction of each RCOC are shown in Figure 1.1.

## **1.2 Significance of Pavement Profile Measurements**

The longitudinal profile along the wheel paths in a pavement can be used to evaluate the roughness of the pavement by computing a roughness index such as the International Roughness Index (IRI). The change in the longitudinal pavement profile over time, which is directly related to the change in roughness with time, is an important indicator of pavement performance. Hence, one aspect of the LTPP program is to collect pavement profile data of in-place pavement sections for use in improving the prediction of pavement performance.

## **1.3 Profile Data Collection**

The primary device used to obtain pavement profile measurements for the SHRP-LTPP program is the Model 690DNC Inertial Profilometer manufactured by K.J. Law Engineers, Inc. Each RCOC operates one Profilometer to collect data within its region. The operation and maintenance of the Profilometer and the storage of the collected data are the responsibility of each RCOC.

However, when a Profilometer is not available, SHRP has elected to use the Dipstick, which is a hand-held digital profiler manufactured by Face Technologies to collect profile data. The Dipstick is also used to obtain transverse profile data in some circumstances. Each RCOC contractor maintains a Dipstick for profile data collection for these circumstances.

A rod and level can also be used to measure pavement profiles if a Profilometer or a Dipstick is not available, or where other special circumstance or requirements rule out the Dipstick or the Profilometer.

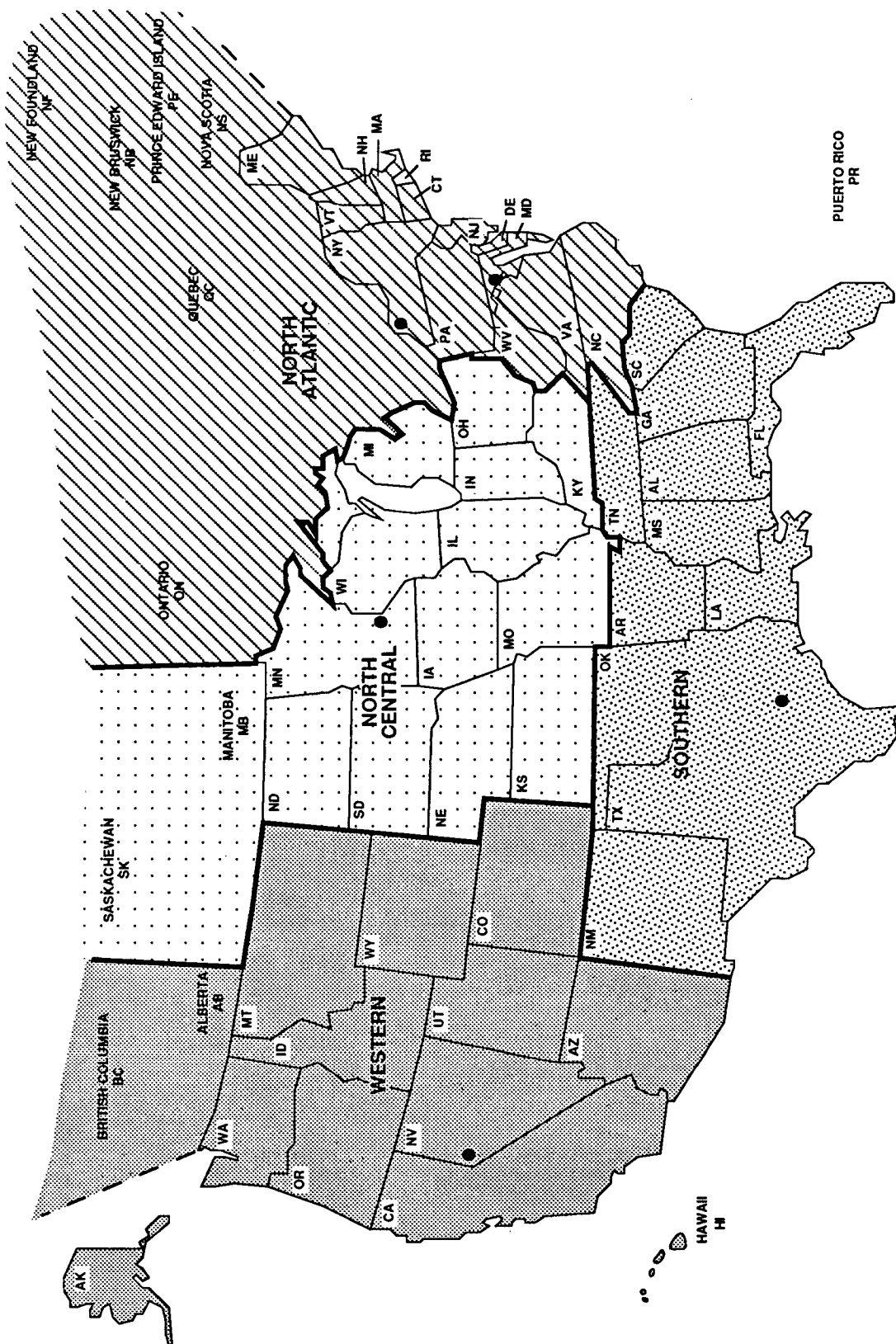


Figure 1.1. SHRP Regions

## **1.4 Overview of the Manual**

This manual describes procedures to be followed when measuring pavement profiles using the K.J. Law model 690DNC Inertial Profilometer, the Face Technologies Dipstick and the rod and level. The manual covers the following:

1. Field Testing
2. Data Collection
3. Calibration of Equipment
4. Equipment Maintenance
5. Record Keeping

This document addresses those aspects of profile measurements that are relatively unique to the LTPP research. Other references should be consulted for general information.

## **2. Profile Measurements Using the K.J. Law Profilometer**

### **2.1 Introduction**

The K.J. Law Model 690DNC Inertial Profilometer measures the longitudinal road profile in the two wheel paths. The system for measuring the road surface profile consists of an optical displacement measuring system and a precision accelerometer for each wheel path. The optical system measures the distance between the vehicle body and the pavement surface, while the accelerometer measures the motion of the vehicle body. Signals from the non-contact sensors of the optical system and the accelerometers are fed into a computer which computes the profile of the pavement. The profile data is recorded on the hard disk of the computer for further processing. The computer terminal shows the profile of the pavement as it is measured.

The device is equipped with a photocell capable of detecting identifying marks on the pavement surface, such as reflective tape or a white painted line. This feature is used to initiate profile data collection. A digital distance encoder attached to the front wheel of the vehicle accurately measures the travelled distance. A generator is provided in the vehicle to supply power to the computer and other electronic equipment. The Profilometer vehicle is equipped with both heater and air-conditioning units to provide a uniform temperature for the electronic equipment carried in the vehicle. The Profilometer vehicle can measure road profiles at speeds ranging from 10 to 55 mph (16 to 88 kmph). For the SHRP-LTPP studies, the test speed will normally be 50 mph (80 kmph).

Three of the four Profilometer vehicles used to collect profile data for the SHRP-LTPP program are identical. They were purchased by SHRP and then sent to the regional contractors. The vehicle used for these Profilometers is a motor home and the distance between the non-contact sensors for these units is 66 in. (167 cm). The fourth Profilometer vehicle, which belongs to the FHWA, has been loaned to SHRP. This unit is in a van. The distance between sensors on this vehicle is 54 in. (137 cm).

Detailed outlines of the operating procedures, calibration, and maintenance requirements of the different components of the Profilometer vehicle can be found in the manuals listed in the References.

### **2.2 Operational Guidelines**

#### **2.2.1 SHRP Procedures**

**Maintenance of Records:** The operator is responsible for preparing and forwarding the forms and records as described in Section 2.6, which relate to testing and maintenance of the Profilometer to the RCOC.

**Accidents:** Insurance coverage for the operator, driver, and the vehicle is maintained by the RCOC. The operator will inform the RCOC as soon as possible after an accident. Details

of the accident should be reported later in writing to the RCOG to assist in any insurance claim procedure which might be affected.

### **2.2.2 General Operations**

The following guidelines related to the general operation of the Profilometer device shall be followed.

#### **2.2.2.1 Temperature Range**

The interior vehicle environment is critical to the operation of the on-board computer. Fixed head disks operate with very close mechanical system tolerances and may be damaged if subjected to large temperature variations or extremes. The computer system should only be operated in a temperature range of 59 to 90°F (15 to 40°C). Further, the maximum rate of change of temperature should not exceed 20°F/hour (11°C/hour). The vehicle is equipped with a propane furnace and an air conditioner to maintain the temperatures within the required range. If the computer is not being operated, the storage temperature can range from -40 to 151°F (-40 to 66°C).

During periods of testing in hot weather, it is suggested that the roof vent or side window in the work area be left ajar and the fan operating when the Profilometer is retired at the end of the workday. If the air temperature will drop below 60°F (16°C), the propane heater should be turned on and set to 60°F (16°C).

#### **2.2.2.2 Disk Drives**

Saving files to the hard disk or floppy disks, or loading files from the hard disk or floppy disks, should not be done when the vehicle is in motion as this can destroy data files. The computer's virtual memory should be used to record all data while the vehicle is in motion.

#### **2.2.2.3 Power Control**

The power to the computer system is routed through a power controller located at the bottom of the computer enclosure. When the controller is in the remote mode, no power will be supplied to the rest of the equipment unless the computer is turned on. If the controller is placed in the local mode, then individual components may be turned on and off.

#### **2.2.2.4 External Power Source**

Power should be turned off to all instruments, computer, and the generator before connecting to an external power source. The external electrical power cord can be connected to a standard 30 amp outlet, or (with an adapter) to a standard 15 amp outlet. The power requirements are 115 volts AC at 10 amperes, or 230 volts AC at 5 amperes. When an external power source is used, a relay will automatically switch from the generator to the external power source. When operating on external power with the sensor lamps turned on,

the battery charger should be activated to keep the 12 volt batteries charged.

### **2.2.3 *Field Operations***

#### **2.2.3.1 Operating Speed**

A constant vehicle speed of 50 mph (80 kmph) should be maintained during a profile measurement run. If the maximum constant speed attainable is less than this due to speed limits, traffic congestion, or safety constraints, then a lower speed as close as possible to 50 mph (80 kmph) should be selected. If the site is relatively flat, cruise control should be used to maintain a uniform speed. It is important during a profile run to avoid changes in speed which may jerk the vehicle or cause it to pitch. Change in throttle pressure or use of brakes to correct vehicle speed should be applied slowly and smoothly.

#### **2.2.3.2 Event Initiation**

During profile data collection, the data collection program uses "event marks" to initiate data acquisition. The event marks are generated by either a photocell event detector or by the operator event pendant.

The photocell event detector uses the white paint stripe on the pavement prior to the test section to initiate data acquisition. Depending on the reflectivity of the paint mark on the pavement, the detection threshold control located on the front of the console may require some adjustment for the photocell to trigger properly. If the pavement surface is bright, the threshold should be lowered. If the pavement is dark the threshold should be increased. Several passes over the section may be required to determine the proper threshold setting. In instances where the existing paint mark on the pavement does not trigger the photocell even with threshold adjustments, reflective pavement marking tape may be placed at the beginning of the section.

If the threshold for the photocell has to be set near zero to enable the photocell to trigger, it could indicate a clouded lens in the photocell. This occurs when the brass inside the photocell corrodes and fogs the lens. The photocell has to be returned to K.J. Law for cleaning.

Sometimes, the photocell event detector may not trigger on pavements with a light-colored surface. If this condition occurs, the operator event pendant should be used instead of the photocell to initiate data collection. This method requires the operator to judge the starting point for data acquisition. A reference point near the starting point on the side of the pavement (e.g., a road sign or a tree) should be used for consistency. Several practice runs may be needed for data acquisition by this method.



### 2.2.3.3 Recording Profile Data

The virtual memory on the DEC computer will be used as the recording medium during a profile run. After the run is completed, the driver should pull over and come to a complete stop at a safe location so the data can be transferred to the hard disk prior to another profile run. On sections where the turnaround distance is relatively short, the operator could complete all runs before saving the data to the hard disk. All data should be transferred to the hard disk and backed up on a floppy disk before the crew leave the test section.

### 2.2.3.4 Inclement Weather and Other Interferences

In some instances inclement weather (rain, snow, lightning, and heavy cross winds) may interfere with the acquisition of acceptable data. In general, profile measurements should not be conducted on wet pavements, particularly when free-standing water is present. In some cases, it may be possible to perform measurements on a damp pavement with no visible accumulation of surface water. In these circumstances, run-to-run variations and potential data "spikes" should be closely watched. A spike threshold value is used to identify spikes. When two consecutive elevations have a difference in excess of this value and the next elevation is such that the middle point becomes either a maximum or a minimum of the three points, a spike is present. The Profscan program (1) uses a spike threshold value of 0.1 in. (0.25 cm). Spikes can be due to field-related anomalies (e.g., potholes, transverse cracks, bumps) or due to - saturation, electronic failures or interferences.

Changing reflectivity on drying pavements due to the differences in brightness of the pavement (light and dark areas) will often provide results inconsistent with data collected on uniform colored (dry) pavements. This could be due to varying accuracy of the light sensing unit due to the rapid changes in reflectivity or to the dark spots resulting from marginal lost lock situations. In such situations, profile measurements should not be performed until the pavement is dry.

In some instances, electromagnetic radiation from radar or radio transmitters will interfere with operations and data recording. If this occurs, the operator should attempt to contact the source to learn if a time will be available when the source is turned off. If such a time is not available, it may be necessary to schedule a Dipstick survey of the test section.

## 2.2.4 *Number of Runs*

This section describes the procedures to be followed to obtain an acceptable set of profile data.

### 2.2.4.1 IRI from DEC

The DEC computer in the Profilometer vehicle records the profile data and computes the IRI of the test section. The IRI of the left wheel path and the right wheel path, as well as a both-wheel path IRI, which is the average of the left and right wheel path IRI are computed.

During each run, the DEC terminal displays the profile of the left and the right wheel paths. Immediately after the run is completed, the terminal displays the computed IRIs and a hard copy of the profile with the IRI values is printed. Before saving the profile data, the operator should enter any comments regarding the completed run that may affect the measured data. These include: failure to maintain correct wheel path; whether saturation light or lost lock light was on; passing trucks; high winds; and rapid acceleration or deceleration.

The degree of run-to-run variability in IRI within a section under normal operating conditions will usually depend on the roughness of the pavement. On new asphalt concrete overlays or new concrete pavements, variation of IRI between runs will be very small. However, rough pavements may cause more variability in IRI between runs. If during testing the operator notes very high run-to-run variations of IRI between runs, testing should cease and the cause of variation should be identified. If the variation is due to equipment problems (e.g., worn shroud cover), the problem should be corrected. If the variations are due to causes beyond the operator's control, such as radar interferences or low sun angle, the operator should decide how to proceed with testing. For example, if the sun is low, the operator could wait until conditions improve and perform testing or leave the test location and test it at a later time.

Once the operator is confident that a minimum of five error-free runs have been completed, the acceptability of the profile runs has to be evaluated using the Profscan program (1).

#### 2.2.4.2 IRI from Profscan

The acceptability of the runs performed by the Profilometer vehicle is evaluated using the Profscan program. The user manual for Profscan is included in Appendix I. Profscan runs on an IBM compatible computer and cannot be run on the DEC machine. The profile data recorded in the DEC is converted to a form that can be read by an IBM compatible machine using the Kermit program. The Kermit program can be called from the Main Menu (see Section 2.3.4).

The Profscan program should be set to the following parameter settings:

- Spike Threshold Value: 0.10 in
- Summary Interval: 100 ft
- Seed (36 ft into run): 'Y'
- % Tolerance on Mean: 1.0
- % Tolerance of Standard Deviation: 2.0

The Profscan program uses the profile data to compute IRI for the left and right wheel paths, as well as a both-wheel path IRI which is the average of the left and right wheel path IRIs. The Profscan program also generates a report of spikes present in the pavement profile. There is a small difference between the IRI computed from the program in the DEC computer and Profscan due to a differences in data initialization in the computer programs.

A minimum of five profile runs should be used with Profscan. If more than five runs are available at a site the user has the option of selecting five runs to be analyzed by Profscan. The profile runs at a site are accepted by the Profscan if the average IRI of the two wheel paths satisfy the following criteria.

1. The IRI of three runs are within 1% of the mean IRI of the selected runs.
2. The standard deviation of IRI of the selected runs are within 2% of the mean IRI.

If the IRI from the profile runs meet the Profscan criteria and the operator finds no other indication of errors or invalid data, no further testing is needed at that site.

#### **2.2.4.3 Non-Acceptance of Runs by Profscan**

If the runs do not meet the Profscan criteria, the operator should perform the following two steps to identify if the variability is the result of equipment/operator errors or pavement related.

1. Review the end-of-run comments of the runs as well as the following factors to determine if any of these factors could have affected the data collected during the profile runs. The factors to be considered are: whether saturation light or lost lock light was on, low sun angle, worn shroud cover, passing trucks, high winds, rapid acceleration or deceleration of vehicle.
2. Review the spike report generated by Profscan to determine if the spikes are the result of field-related anomalies (e.g., potholes, transverse cracks, bumps) or due to saturation, electronic failures or interferences. This can be analyzed by reviewing the Profscan reports and seeing if the spikes occur at the same location in all runs.

If the variability between runs or the spikes are believed to be operator or equipment error, identify and eliminate, correct, or avoid (as in the case of non-ideal lighting conditions) the cause of the anomalies and make additional runs until a minimum of five runs free of equipment or operator errors are obtained. Where anomalies in the data are believed to be due to pavement features, rather than errors, a total of nine runs should be obtained at that section. If the data from the last four runs are consistent with those for the first five (in terms of variability and the presence of pavement-related anomalies), no further runs are required. If the data from the last four runs differ from those for the first five runs, the operator should reevaluate the cause of the variability or apparent spike condition, and make additional runs until five error-free runs have been obtained. Once testing is completed, the Profscan program should be used to evaluate the data.

### 2.2.5 *Labelling Disks*

Disk labeling standards are important so that all personnel will be able to understand where the data originated based on the disk label. Labels will be created using the following format for GPS sections:

1. Line 1: "ID# xxxxx" where xxxxx is the SHRP section number.
2. Line 2: "Volume x of y" where x is the number of the current disk in the set and y is the total number of disks in the set.
3. Line 3: "Copy # x" where x is the number, usually 1 to 3.
4. Line 4: "Profilometer SN xxx" where xxx is the serial number of the Profilometer vehicle.
5. Line 5: "MM/DD/YY" where MM/DD/YY is the month, date and year that the testing was performed.

Example: GPS Section

ID# 263456, 264567, 265678  
Volume 1 of 1  
Copy 1 of 3  
Profilometer SN 007  
Date 08/28/91

The above label tells that the data was collected from GPS sections 263456, 264567 and 265678 on August 28, 1991.

## 2.3 Field Testing

### 2.3.1 *General Background*

Collection of profile data is the primary responsibility of the Profilometer operator. The procedures to be followed each day prior to and during data collection with respect to daily checks of vehicle and equipment, start-up procedures, setting up the software for data collection and using the software for field data collection are described in the following sections.

The following sections will describe the procedures to be followed when testing General Pavement Studies (GPS) sections. Some of the procedures to be followed for testing Specific Pavement Studies (SPS) sections are different than the procedures for GPS sections. Section 2.7 of this manual outlines the procedures for SPS sections which differ from the procedures for GPS sections.

### ***2.3.2 Daily Checks on Vehicle and Equipment***

The operator should use Daily Check List form given in Appendix V to check the vehicle and the generator at the start of the day. It is important to maintain the equipment at a proper operational temperature as noted in section 2.2.2.1. If the weather is very damp, the heater should be turned on to remove moisture from inside the unit. The sensor and receiver glass may require cleaning more than once during the day.

### ***2.3.3 Starting the Generator***

The following procedure should be used for starting the generator.

1. Before starting the generator, ensure that all external power sources are disconnected and that all instruments and the computer are turned off.
2. Depress the Start/Stop rocker switch to start the generator. Release the switch when the engine starts. If the generator does not start in a few seconds, wait ten seconds and try again. If further difficulty is encountered, consult the operator's manual for the generator.
3. Once the generator is operating, wait for a few minutes to allow the generator to come up to speed and to stabilize. If the temperature is cool and damp, or cold, turn the air intake to winter conditions. If the idle is rough, adjust the fuel-to-air mixture (adjustment on float bowl) to obtain the ideal setting. If the generator still runs roughly, the operator may have to clean the carburetor of the generator. Consult the operator's manual for the generator for details. If the generator still runs roughly, it may need to be serviced.
4. Any equipment which uses power supplied by the generator should not be turned on until the generator has stabilized. A clicking sound indicates that the generator has stabilized and that it is safe to turn on the various equipment powered by the generator. If the voltage on the auxiliary battery has dropped below 12 volts, turn on the charger for the auxiliary battery. The battery charger is mainly used to keep batteries charged when the unit is plugged to an external power source or to provide additional charge to increase the intensity of sensor lights when testing pavements with dark surfaces. NOTE: Do not turn on auxiliary battery charger if the vehicle has a solenoid that ties the vehicle's main and auxiliary batteries and charges them at the same time.
5. Warm up the system prior to performing calibration checks or performing tests. This may be as little as 15 minutes in the summer or as much as 30 minutes in the winter.

### 2.3.4 Setting Up the Software

Ensure that the ambient temperature and rate of change of temperature within the vehicle is within the system operating range (see Section 2.2.2.1). Proceed in the following order:

1. Place the system disk in the upper drive (DU1) of the DEC computer. Make sure that the write-protect notch is on the left side.
2. Turn on the computer or press the "Restart" button if power is already on. The system will access the disk and load the operating system into memory. Verify that the run light is on and the DC OK light is illuminated.
3. If the monitor does not respond, then:
  - a. Depress the "Restart" button on the DEC PDP 11/83 front panel.
  - b. Depress and hold [Ctrl] and then press C. Do this twice.
  - c. Within one minute the terminal should respond with:

*Message 04 Entering Dialog Mode*  
*Commands are Help, Boot, List, Setup, Map and Test*  
*Type a command then press the [RETURN] key.*
  - d. Type "BOOT DU1" and press the [Return] key. The upper drive indicator should light, indicating that the disk is being accessed.
  - e. If the start up message does not appear within one minute, boot the system with the backup system disk.
  - f. If the system still does not respond, or the "Halt" indicator light comes on, the DEC computer needs servicing. This should be performed by an authorized DEC service center.

Once the software has been loaded, remove the system disk from the drive. The monitor will display the Main Menu:

- A     FORMAT AND INITIALIZE (calls the format - initialize menu)
- B     RUN BACKUP (calls the file backup menu)
- C     RUN CALIBRATE (runs the calibrate program)
- D     LIST DIRECTORIES (calls the directory menu)
- E     TIME DATE (permits changing time and/or the date)
- F     RUN REPLAY (runs the profile replay utility)
- G     HEADER MENU (lists, deletes and copies header files)
- I     TRANSFER FILES TO IBM (calls the KERMIT routine to transfer files to a format that can be read by a IBM- compatible computer)

P     **RUN PROFILE** (runs the profile program)  
H     **PRINT HELP FILE** (prints the HELP file)  
X     **Exit**

All commands are executed by typing the appropriate letter from the menu and then pressing the [Return] key. If the operator makes a mistake, the typed character can be deleted with the [Backspace] key.

### **2.3.5 Calibration Checks**

The following calibration checks should be performed before profile measurements are taken.

1.     **Displacement Sensor Check**
2.     **Bounce Test**

#### **2.3.5.1 Displacement Sensor Check**

The displacement sensor check is a test of the non-contact displacement sensors to determine if they are within tolerance. Distances from the vehicle body are measured during this test, so extreme care must be taken to ensure that the vehicle is absolutely still during this check. If any movement occurs during this check, for example due to wind, it may be necessary to move the vehicle to an enclosed building, or park it on the side of a building protected from the wind. The displacement sensor check should be repeated separately for left and right sensors. To initiate the displacement sensor check, select "C", Run Calibrate, from the Main Menu (see Section 2.3.4). Then the following menu will be displayed.

K     **Enter Scale Factor Via Keyboard**  
D     **Record all Scale Factors on Disk**  
A     **Accelerometer Calibration**  
L     **Left Displacement Sensor Calibration**  
R     **Right Displacement Sensor Calibration**  
B     **Display Profile for Bounce Test**  
S     **Display Left and Right Displacement Sensors**  
G     **Display Accelerometer Outputs**  
X     **Display Rate Gyro Output**  
W     **Wheel Encoder Calibration**  
X     **Exit Program**

The following steps are to be followed during the displacement sensor check.

1.     Enter "R" and [Return] to start the non-contact sensor calibration for the right sensor ("L" for the left sensor).
2.     A prompt to insert the calibration plate under the light source and to level it is then displayed. Place the calibration plate below the light source. Level the plate by adjusting the three leveling screws until the bubble on the plate is

centered. If the plate cannot be leveled because of rough pavement grade, move the vehicle to a more level and smooth surface.

3. After the plate is levelled, enter "Y" and [Return], which signals the computer to take 200 readings and compute a mean for the lower level.
4. The computer program will then prompt for the insertion of the 1.0 in. (2.5 cm) block. Carefully place the block on the plate, under the light source. Enter "Y" and [Return]. The program will then take 200 readings and compute a mean for the upper level. Then, the difference between the means of the lower and upper levels will be computed. If this difference is within  $\pm 0.01$  in. ( $\pm 0.25$  mm) the sensor has passed the calibration check.
5. If the differences is more than  $\pm 0.01$  in. ( $\pm 0.25$  mm) a message that the calibration value is out of tolerance is displayed.
6. Enter "N" to the question if a new calibration factor is to be computed and repeat the calibration procedure until the difference of readings is within tolerance (repeat calibration procedure a maximum of 3 to 4 times to achieve this condition).
7. If a difference of readings within tolerance cannot be achieved (after repeating the calibration procedure 3 to 4 times), answer "Y" to the prompt if a new calibration factor is to be computed.
8. Save this computed calibration factor in the virtual memory. Also complete the form Profilometer Calibration Log (see Appendix V) and note that it is a field calibration. This calibration factor is used for tests that are performed. However, this factor will be lost when the power to the computer is turned off. NOTE: The calibration factor computed during the field displacement sensor check should not be saved on the system diskette.

If difficulty is encountered with calibration or checking of the non-contact sensors, it may be beneficial to check the light output with the oscilloscope for proper signal magnitude and alignment.

### 2.3.5.2 Bounce Test

The bounce test is used to check the accelerometers which senses the movement of the vehicle body. The following procedure is used to conduct this test.

1. Park the vehicle.
2. From the Main Menu (see Section 2.3.4) select "P" (run profile).
3. Answer "Y" to the question "Do you want to record profile".



4. Answer "N" to the question "Do you want to use an existing header file".
5. Then the Surface Profile Setup Menu (see Section 2.3.6.1) will be displayed. In this menu select "T" and enable the Test Mode Oscillator.
6. Proceed to the Run Identification Menu (see Section 2.3.6.2) and input any arbitrary six characters to the section number.
7. Proceed to the Run Control Method Menu (see Section 2.3.6.5) and select: Start Method Pendant and Stop Method Pendant.
8. Proceed to Options Setup Menu (see Section 2.3.6.6) and change the wheel path as both and the averaging interval to 100.
9. Proceed to the System Change Setup Menu (see Section 2.3.7) and press [Return] to enter the run mode.
10. Depress the start pendant, then exit the vehicle. Stand on the rear bumper of the vehicle and rock the vehicle back and forth, and side to side by shifting your weight from foot to foot.
11. During this "bouncing" of the vehicle, the output displayed in the monitor should remain static and show no or very little variation. The stop pendant should then be depressed after 15-30 seconds.
12. The computed IRI should normally be less than 5. If the IRI exceeds 10, usually this is the result of lost lock. Perform the test again, but on a different surface. If the IRI is still high, the accelerometers should be calibrated using the procedure outlined in Section 2.4.3.

### ***2.3.6 Entering Header Information***

Before testing a section, the operator has to go through a series of header menus in the software and input data relevant to that section as well as change several default settings in these menus.

Before beginning this process the operator should complete the following:

1. Make sure that the computer shows the current date and time.
2. Check that the power is supplied to the sensors and sensor lamps. The lost lock lights should be lit if power is not supplied. After supplying power it may take a few moments before the lost lock lights go out. If the lost lock light is on continuously the bulb may be burnt.

3. The shrouds must be lowered to approximately 1 in. (2.54 cm) from the pavement to keep the sun from washing out the signal to the displacement receivers.

To begin the process of entering header information select "P" and [Return] if in the Main Menu (see section 2.3.4) or type "Run Profile" and [Return] from the monitor. The program will first load the system calibration factors from the disk. If the file containing the calibration factors (SCALE.CAL) is not found or if there is an error in reading the data, an error message will be displayed. If this occurs, the operator should re-boot the computer, making sure that the vehicle is stationary during the booting period. Frequently the error message occurs because the file SCALE.CAL is not copied to the memory and all that is needed is for the operator to copy SCALE.CAL to the virtual memory.

Once the scale factors are read, the program will prompt the operator with the following questions:

1. "Do you want to record profile." The operator should respond with a "Y" and [Return].
2. "Do you want to use an existing header file." The operator can respond with a "Y" or "N". If the operator types "Y", the program will generate a request for a header file name. Once the operator enters a file name, the parameters stored in the file will be read and the program will advance to the main menu where it is possible to go directly to profile computing mode or to modify the parameters read from the file. When using an existing header, the section number under the Run Identification Menu (see Section 2.3.6.2) must be reentered to update the DEC automatic file date sequence because the Profscan program uses the date to match files with headers. If this is not done an error message will appear when using Profscan. However, usually the operator will answer "N".

If the operator responds with "N", this answer will take the operator through the following header generation menus.

1. Surface Profile System Setup
2. Run Identification
3. Run Location
4. Run Conditions
5. Run Control Method
6. Options Setup

The first menu to be displayed when the operator answers "N" to the question "Do you want to use a existing header ?" is the Surface Profile System Setup.

### 2.3.6.1 Surface Profile System Setup

The structure of this menu is shown below.

DATE DD - MM - YY      TIME HH:MM:SS

A    DRIVER DISPLAY UNIT MILES  
B    FILTER WAVELENGTH 300. (feet)  
C    GRAPHIC SCALE 1.00 (inches)  
D    GRAPH LENGTH 800 (feet)  
E    PRINT LAST SCREEN ON EXIT ENABLED  
H    HELP  
P    FORM FEED  
T    TEST MODE OSCILLATOR DISABLED

enter LETTER for option, RETURN to proceed, or X to exit

The only item that needs to be changed in this menu is the driver display unit. which must be changed to feet. To make this change select "A" and [Return] to toggle the display units to feet. Thereafter, press [Return] to proceed to the next menu.

### 2.3.6.2 Run Identification

A    SECTION NUMBER 263456  
B    RUN NUMBER 1  
D    SHRP FILE NAME 26345691.031  
C    DEC FILE NAME B63456.D91  
G    AUTOMATIC DEC FILE NAME GENERATION ENABLED  
H    AUTOMATIC DEC FILE NAME INCREMENTS ENABLED  
E    OPERATOR/DRIVER xxxxxxxxxxxxxxxxxx (16 MAX)

enter LETTER for option, RETURN to proceed, or X to exit

In this menu the section number and the operator/driver fields have to be completed. To input the current test section number, the operator should press "A" and [Return]. The program will then accept the entry of the six-digit test section number for the GPS section (e.g., 263456). The SHRP file name and DEC file name will be automatically generated (SHRP file name 26345691.031, DEC file name - B63456.D91). The DEC computer filename will be the same as the SHRP six-digit section number for GPS test section. The operator will then select the letter "E" and [Return] to enter the operator/driver names. Upon completion of this menu press [Return] to proceed to the next menu.

### 2.3.6.3 Run Location

A    ROAD DESCRIPTION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx (32 MAX)  
B    LANE MEASURED xxxxxxxxxxxxxxxxxx (16 MAX)

- C DIRECTION xxxxxxx (8 MAX)
- D HORIZONTAL OFFSET xxxxxxxxxxx (12 MAX)
- E BEGINNING DESCRIPTION xxxxxxxxxxxxxxxxxxxxxxxxxxx (24 MAX)
- F ENDING DESCRIPTION xxxxxxxxxxxxxxxxxxxxxxxxxxx (24 MAX)

enter LETTER for option, RETURN to proceed, or X to exit

All items in this menu must be completed. Entering the appropriate letter and pressing [Return] allows the insertion of the required entry. Each entry is terminated by the [Return] key. For road description enter the route number. After filling in the appropriate data press [Return] to access the next screen.

#### 2.3.6.4 Run Conditions

- A ROAD SURFACE MATERIAL xxxxxxx (8 MAX)
- B ROAD CONDITION xxxxxxx (8 MAX)

##### WEATHER

- C TEMPERATURE xxxxxxx (8 MAX)
- D CLOUD CONDITION xxxxxxx (8 MAX)
- E OTHER xxxxxxxxxxxxxxxxxxxxxxxxxxx (24 MAX)

enter LETTER for option, RETURN to proceed, or X to exit

Entering the appropriate letter and pressing [Return] allows the insertion of the required entry. Each entry is terminated by the [Return] key. The road surface material should be entered as A-CC if the surface material is asphalt, or as P-CC if the surface material is concrete. The road condition should describe the surface condition of the pavement. The surface condition can be described as v. good (very good), good, fair or poor depending on the observed surface defects. The temperature should be the air temperature at the time of test. The cloud condition can be described either as clear, p. cloudy (partly cloudy) or cloudy. The Other field is used to indicate conditions that interfere with the data collection process such as high traffic volumes, wind conditions and high intensity of the sun. Upon completion of this menu, press [Return] to proceed to the next menu.

#### 2.3.6.5 Run Control Method

- A START METHOD PENDANT
- B STOP METHOD PENDANT

enter LETTER for option, RETURN to proceed, or X to exit

This menu is used to select the start and end methods for the profile run. Select the start and stop method using the following steps.

1. "A" toggles between pendant and photocell.

2. "B" toggles between pendant, photocell, and distance. When distance is selected as the ending method, the operator is prompted to enter the length of the run.

The photocell event detector should be used as the start method where possible. If the photocell event detector cannot be used (e.g., light colored pavement surface), the operator event pendant should be selected. The stop method to be used is "distance" irrespective of the start method. For GPS sections a distance of 500 feet should be used for the length of the run. Upon completion of this menu press [Return] to proceed to the next menu.

### 2.3.6.6 Options Setup

I	INDEX <u>ENABLED</u>
R	RIDE QUALITY INDEX <u>IRI</u>
W	WHEEL PATH <u>RIGHT</u>
A	AVERAGING INTERVAL <u>500</u> (feet)
B	INDEX CALCULATION SPEED <u>50.0</u> (mph)
E	FILTER REINITIALIZATION <u>DISABLED</u>
S	STORE HEADER OPTIONS

enter LETTER for option, RETURN to proceed, or X to exit

The fields wheel path and averaging interval need to be changed in this menu. Wheel path should be set to "BOTH" to cause the computed ride quality index to be displayed as the average across both wheel paths. This is done by pressing "W" and [Return] twice. The averaging interval should be changed by pressing "A" and then entering 100. When the Index Option switch is set to "ENABLED" the DEC computes the specified ride quality index. When the Ride Quality Index is set to IRI, the International Roughness Index (IRI) is computed for each run. The Index Calculation Speed, which is used to compute the ride quality index, should always be set to 50 mph regardless of the measurement speed of the Profilometer.

### 2.3.7 Data Collection

Once all the header menus are completed, the System Change Setup Menu will be displayed.

#### SYSTEM CHANGE SETUP MENU

A	SYSTEM SETUP
B	RUN IDENTIFICATION
C	RUN LOCATION
D	RUN CONDITIONS
E	RUN CONTROL
F	OPTIONS SETUP
H	RECALL EXISTING HEADER
S	STORE HEADER SETUPS

enter LETTER for option, RETURN to RUN, or X to exit

Choices "A" through "F" sends the operator to the menus previously discussed. After all of the header file information has been entered, the header file should be saved to the virtual memory and the hard disk (DU3). This is done repetitively by selecting "S" from the menu and then selecting the appropriate drive and entering the six digit test section number at the prompt.

The profile data collection program has to be started to begin data collection. Make sure that a SHRP-LTPP Profilometer Field Activity Report form (see Appendix V) is ready to record the DEC IRIs. To start the profile data collection program, press [Return] from the System Change Setup Menu.

Once these steps are completed, the Profilometer device is ready to take measurements. The following steps should be followed during profile measurements.

1. About 2,000 ft. (610 m) before the test section start the profile data collection program. A graphical display is then generated with the message "Not Recording".
2. The guidelines given in Section 2.2.3.1 regarding the operating speed should be followed. The driver should attain the constant test speed at least 300 feet (91.5 m) before data collection begins.
3. Press the start pendant to arm the photocell after passing the lead in stripe located before the test section. The message "photocell alert" is displayed on the monitor.
4. Once the event mark is detected, the display is erased and the recorded profile starts from the beginning of the grid. Observe if the lost lock or saturation lights come on during the run. If the photocell does not trigger when the event mark is passed, follow the procedure outlined in Section 2.2.3.2.
5. After the test section has been traversed and the computer has computed the DEC IRI, write the value on the SHRP-LTPP Profilometer Field Activity Report Form (see Appendix V). Note any factors that could have affected the computed IRI in the Profilometer Field Activity Report Form.
6. After the computer gets out of the profile display mode, type any comments pertaining to the run (e.g., lost lock or saturation lights come on during the run, any other factors that could affect the measured profile) and then press [Return].
7. Thereafter, the driver should stop the vehicle at a suitable location so the data can be saved on the hard disk. This should be done immediately after each run since the profile data stored in the virtual memory can be lost if the power to the computer fails. Where turn around distances are relatively short, the

operator may wait to transfer the data to the hard disk until all runs have been completed.

8. Follow the procedures outlined in Section 2.2.4 to obtain a set of acceptable runs at a site.
9. Once testing at a site is completed make backup copies as outlined in Section 2.3.8. The order to be followed in turning off the equipment is: (1) IBM compatible computer (2) other devices (3) arrow board (4) sensors and (5) DEC computer. The operator should verify that the form "Status of the Region's Test Section" (see Appendix V) is filled before leaving the test site.

### ***2.3.8 Data Backup***

All profile data is to be backed up to a floppy disk from the DEC computer immediately after testing is completed at a section. The operator should also create a backup copy of all Profile test data on a IBM-compatible disk. The Profile data collection crew should not leave a test site unless all data has been backed up. At the end of each day, an additional two complete backup copies will be made of all Profilometer test data on IBM-compatible floppy disks. These additional copies must be removed from the vehicle whenever testing is not in progress.

The system diskette containing the Profilometer operating program and configuration files should be removed from the vehicle when the operator is not with the equipment. New backup copies must be made each time a change is made to the calibration factors.

## **2.4 Calibration**

### ***2.4.1 General Background***

The non-contact sensors on each Profilometer device were initially calibrated by the manufacturer to an accuracy of  $\pm 0.01$  in ( $\pm 0.25$  mm). The DMI (encoder) is initially calibrated to an accuracy of 0.47%. The calibration of the non-contact sensors, accelerometers and the distance encoder has to be done periodically to ensure that accurate data is being collected. However, the calibration of this equipment should be done whenever problems are suspected. The relatively stable nature of the Profilometer electronics would indicate monthly calibrations are sufficient. Any changes in the calibration factors obtained during calibration should be noted in the Profilometer Calibration Log (see Appendix V). All calibrations should be performed indoors on a level surface using an external power source.

### ***2.4.2 Calibration of Non-Contact Sensors***

The calibration procedure is essentially the same as that described in Section 2.3.5.1, except for the following changes. If the difference between the two readings is within tolerance (see step 5, Section 2.3.5.1), the calibration factor need not be changed. However, if a message

is displayed indicating that the difference is not within tolerance (see step 5, Section 2.3.5.1), a new calibration factor should be obtained. Answer "Y" to step 6 in Section 2.3.5.1 to obtain the new calibration factor. This new calibration factor should be saved on the system disk and the backup system disk. If the factor is not saved, it will be lost when the calibration program is exited. This factor should also be noted on the Profilometer Calibration Log (see Appendix V).

### *2.4.3 Calibration of Accelerometers*

The accelerometer has a special calibration coil wound on the sensing mass of the transducer. A current through this calibration coil exerts a force on the sensing mass which is interpreted by the accelerometer as an acceleration. The analog accelerometer electronics are designed so that the computer can switch a precise current through the calibration coil to represent exactly 1g (32.172 ft/sec<sup>2</sup> or 9.81 m/sec<sup>2</sup>). The calibration coil is aligned with the sensing axis of the accelerometer so that accurate calibration can be performed even if the vehicle is not level. An accelerometer "scale factor" is computed so that the A/D converter output change, due to the coil current representing 1g excitation, when multiplied by the "scale factor" results in exactly a 1g change. During calibration the displacement of the vehicle body is measured. Therefore, care must be taken so that the vehicle does not move during the calibration test. The following steps should be followed to calibrate the accelerometers.

1. From the Main Menu (Section 2.3.4) select "C" followed by [Return] to enter the calibration menu. The menu shown in Section 2.3.5.1 is displayed.
2. Enter "A" and [Return] to start the accelerometer calibration. When this command is entered, the program takes 200 readings of each accelerometer, then computes and displays the mean as the zero value on the monitor.
3. Turn on the 1g test current to each accelerometer. This causes 200 more readings to be taken on each accelerometer. The 1g mean is computed and the program takes the difference between the means for each accelerometer.
4. If the 1g values are more than 1% away from nominal values, a message that calibration values are out of tolerance is displayed.
5. If "Y" is the response to the prompt for new scale factors, the new scale factors are computed and stored in memory.
6. This scale factor should be saved on the system disk as well as on the backup system disk. The new scale factors will be lost if the program is exited without saving the factors.

### *2.4.4 Calibration of Front Wheel Distance Encoder*

Distance travelled by the vehicle as well as the vehicle velocity are measured by an encoder mounted on the left front wheel. The encoder output is demodulated by the distance encoder



signal conditioning board and provides pulses to the computer for the computation of distance. The distance encoder produces two signals in quadrature (one signal is delayed by 90 degrees) at 20 pulses per 1 ft. (0.3 m) traveled. The quadrature detector signals allows true detection of motion in the presence of vibration in the encoder assembly.

To perform the encoder calibration, an accurately measured section 1,000 ft (305 m) to a mile ( 1610 m) long must be utilized. When it is logistically impossible to use an existing section (e.g., one established by a state highway agency) a new section will have to be measured out. A tape measure should be used to measure out a 1,000 ft (305 m) section on a reasonably level pavement with low traffic volume. In this section the start and the end should be clearly marked. A right-angled square which is set flush with the door of the vehicle should be used to accurately locate the starting point of the test section. Use this same method at the end of the test section to accurately locate the end position. This procedure will ensure that the vehicle will accurately traverse the distance set out at the site.

The following steps should be followed when performing the calibration.

1. From the main menu (Section 2.3.4) enter "C", followed by the [Return] to get into the calibration menu. The menu shown in Section 2.3.5.1 will now displayed.

2. Enter the letter "W" and [Return].

3. The monitor will display the message:

"Driver display to be in feet or miles?"

The operator should select the feet option. The program will then display the current distance encoder scale factor as read from the disk. The factor has units of feet per 100 pulses (i.e., 20 pulses per foot is 5 ft per 100 pulses).

4. The program will display the following options:

- a. "Drive a Measured Distance" (Type 'D')
- b. "Simulate Distance encoder with Oscillator" (Type S)
- c. "Exit" (Type 'E')

Select "D" and [Return] which will require the vehicle to be driven over a measured distance.

5. Start the distance measurement with the pendant and slowly traverse the section. End the distance measurement with the pendant. The operator will enter the length of the section in feet.
6. The program will then compute a new scale factor. The operator will have the option of saving this new scale factor on the system disk before exiting the program and returning to the main program.

## **2.5 Equipment Maintenance and Repair**

### ***2.5.1 General Background***

The responsibility for equipment maintenance and repair rests with each RCOC. The decisions required for proper maintenance and repair should be based on the testing schedule and expedited as necessary to prevent disruption of testing. Maintenance activities should be performed prior to mobilization for testing. During a testing period there will be little time to do more than the required daily checks prior to testing. Specific, detailed maintenance procedure are contained in the manuals provided with each piece of equipment (see References). The operator must become familiar with the maintenance recommendations contained in all equipment manuals. Maintenance/repair work to be performed can be classified as: routine maintenance, preventive maintenance and unscheduled maintenance.

### ***2.5.2 Routine Maintenance***

Routine maintenance includes work that can be easily performed with minimal disassembly of an equipment by the operator. The Daily Check List (see Appendix V) includes a list of maintenance activities to be performed every day. These procedures include checking the fluid levels in the vehicle, checking the battery cable connections, checking vehicle lights, and checking tire pressure which is required for accurate distance measurement. These items are the most basic and easily performed maintenance measures and should always be done prior to using the equipment every day.

### ***2.5.3 Scheduled Major Preventive Maintenance***

Scheduled major preventive maintenance services will include much more than the routine checks. These service will require some disassembly of the equipment and will require capabilities beyond the skill of the operators and RCOC staff. The SHRP Major Maintenance/Repair Report Form (see Appendix V) will be used by the operator to report the necessary services performed and will also serve to inform the RCOC of the condition of the Profilometer vehicle on a regular basis.

### ***2.5.4 Unscheduled Maintenance***

These are unscheduled repairs. These repairs must be reported on the SHRP Major Maintenance/Repair Report form as an unscheduled maintenance activity.

### ***2.5.5 Specific Repairs/Adjustment Procedures***

#### ***1. Non-Contact Sensor Lamp Replacement***

1. Turn off the power to the sensor lamps.
2. Loosen the Allen head screws (#8) which hold the cylindrical sleeve

containing the 100 watt lamp.

3. Mark the position of the adjustable block so that it will be easier to reinstall. Loosen the two flat head screws holding the lamp and remove the burnt out lamp.
4. Install the new lamp, making sure not to touch it with the fingers.
5. After tightening the lamp, install the adjustable block and make sure that it is back in its original place.

## **2. *Non-Contact Sensor Lamp Adjustment***

1. Turn on the power.
2. Hook the oscilloscope to the panel. Channel 1 - reference, Channel 2 - road.
3. Adjust the scope to center road pulse between the two reference pulses. Adjust light height and location to obtain maximum light intensity or peak on the oscilloscope, using either a smooth concrete or asphalt surface as the reference plane. The peak should be about 2/3 of that obtained from the reference light source. Typically reference pulses will be 12-15 volts and pavement pulses 4-6 volts. The aperture on the camera lens can be used to adjust the light source up or down. It is normally set one notch from fully open. The final step should be to focus the light source for maximum intensity by using the focus adjustment provided on the lens.
4. Calibrate the lamp using the calibration procedure outlined in Section 2.4.2.

## **2.6 Record Keeping**

There are seven reports that should be forwarded to the RCOC by the Profilometer vehicle operator. The seven reports that are required are as follows:

1. Daily Check List
2. SHRP-LTPP Major Maintenance/Repair Activity Report
3. SHRP Profilometer Maintenance Data - Gasoline
4. Profilometer Calibration Log
5. SHRP/LTPP Profilometer Field Activity Report
6. Status of the Region's Test Sections
7. PROFSCAN Reports

### ***2.6.1 Daily Check List***

In order to maintain the Profilometer device and various associated equipment in proper operational conditions, a daily check of all items covered in the Daily Check List Form (see Appendix V) should be performed. The operator should check off each listed item as being within correct operational levels or conditions as stated in the operating manuals.

### ***2.6.2 SHRP-LTPP Major Maintenance/Repair Activity Report***

The vehicle and equipment operating costs are monitored with this form. All maintenance and repairs performed on the vehicle or equipment should be reported on this form (see Appendix V). These include scheduled maintenance as well as unscheduled maintenance. This form should be submitted along with all receipts for maintenance activities.

### ***2.6.3 SHRP Profilometer Maintenance Data - Gasoline***

The Maintenance Data - Gasoline Form (see Appendix V) is used to monitor the gasoline consumption. When filling the form the Profilometer vehicle identification number is used as the serial number. The RCOG for the region, names of crew members, the number of gallons of gasoline purchased, the cost of the purchase and the odometer reading need to be recorded in this form.

### ***2.6.4 Profilometer Calibration Log***

All calibrations should be recorded by the operator in the Profilometer Calibration Log (see Appendix V). The procedures for performing these calibrations are outlined in Section 2.4. After performing each calibration test the operator should enter the old scale factors and, if needed, the new scale factors on this form. This form should also be filled if a new scale factor is computed during the calibration checks performed prior to testing each day (see Section 2.3.5.1).

### ***2.6.5 SHRP-LTPP Profilometer Field Activity Report***

The Field Activity Report (see Appendix V) records all activity to and from a site, as well as activities at the test site. Section identification information, DEC IRIs as well as any factors which might affect test data interpretation that could not be recorded in the computer are noted in this form. The Field Activity Report should be filled out for all travel days, all testing days, and any time operator performs maintenance on the equipment. It is important that reports for test days be completely filled out with all section identification data so that the report may be easily matched to the profile data. For travel only days, the section for which the traveling is being done should be noted. This form also includes a space for the Profilometer operator to acknowledge that the Daily Check List (see Appendix V) was performed on the equipment and the vehicle.

### ***2.6.6 Status of the Region's Test Sections***

The Status of the Region's Test Section form, (see Appendix V) should be filled out at every test section. Recent maintenance or rehabilitation activities, condition of paint marks, missing SHRP signs and delineators as well as any other comments regarding the test section should be recorded in this form.

### ***2.6.7 Profscan Reports***

Two reports are generated for each test section by Profscan. The Summary Report contains a statistical summary of the IRIs of the different runs at a test site. The second report, the Spike Report, contains a record of the spikes detected in the pavement profile. If no spikes are detected at a section this report is not produced. Both these reports must be attached to the associated Field Activity Report. The Profscan Manual (Appendix I of this book) contains a sample Summary Report and Spike Reports.

## **2.7 Testing SPS Sections**

### ***2.7.1 General Background***

This section describes procedures to be followed when testing SPS sites. The procedures for testing SPS sites are based on those used for GPS sites. This section describes the exceptions to the GPS procedures that must be followed for the SPS sites.

A SPS site consists of a number of test sections with a transition area between the different sections. During a Profilometer run at a SPS site, profile data are collected for the entire site, which includes test sections as well as transition areas.

### ***2.7.2 Length of Test Sections***

Unlike the GPS test sections which are always 500 ft (152 m), the length of SPS sites vary. The virtual memory in the computer can only store profile data up to three miles. If an SPS site is longer than 3 miles (4.8 km) it is necessary to test it in sections. If two files exist for one SPS site the SHRP-LTPP Profilometer Field Report (SPS) shown in Figure 2.1 should be filled out and attached to all generated profiles. For example, a SPS-6 site which is in Michigan (State ID = 26), when broken into two sections, would create two files 2606X1 and 2606X2 (see Section 2.7.6 for file naming convention). These filenames as well as the sub-sections contained in each file should be recorded as shown in Figure 2.1. A blank Profilometer Field Activity Report - SPS is included in Appendix V.

## SHRP-LTPP Profilometer Field Activity Report - SPS

SHRP Region: North Central Region

State: Michigan

SPS Section: SPS-6

Number of Sections used in Profilometer Runs: 2

File Name: 2606X1

Stations: 122+50/134+00/154+50/177+50/181+50 SHRP ID: 260601

260602

260603

260604

260605

File Name: 2606X2

Stations: 291+00/413+50/424+50/429+00 SHRP ID: 260606

260607

260608

260609

File Name: \_\_\_\_\_

Stations: \_\_\_\_\_

SHRP ID: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Figure 2.1. SHRP-LTPP Profilometer Field Activity Report—SPS

### ***2.7.3 Operating Speed***

The guidelines described in Section 2.2.3.1 should be followed when testing SPS test sections. When SPS sites are tested, the transition area between the sub-sections may be used to adjust the vehicle speed to 50 mph before the next section is tested. If there is traffic in front of the Profilometer vehicle, its speed can be initially decreased in the transition section to increase the distance to vehicles ahead. The Profilometer can then be brought up to a constant speed of 50 mph (80 kmph) before entering the next test section.

### ***2.7.4 Event Marks***

Event marks are used to identify the starting point of each test section within a SPS site. The Profscan program uses these event marks to compute the IRI of each test section.

### ***2.7.5 Number of Runs***

Each test section within a SPS site should satisfy the Profscan criteria (see Section 2.2.4.2). The Profscan program is capable of computing the IRI of the individual test sections within a SPS site by identifying the test sections using the event marks. The operator should study the IRI computed for each run to ensure that repeatable data are obtained between runs. The procedure outlined in Section 2.2.4 for GPS sites should be followed in order to obtain an acceptable set of runs at a SPS site.

### ***2.7.6 Header Generation***

The procedures outlined in Section 2.3.6 for header generation for GPS test sites should be followed for SPS test sites. However, differences exist for SPS sites in the following menus.

#### ***1. Surface Profile System Setup (see Section 2.3.6.1):***

The Graph Length is the length that can be seen on one screen of the monitor. The available graph lengths are 800, 1600 and 3200 ft. Depending on the length of the SPS site select an appropriate graph length. For long SPS sites the entire length cannot be displayed in a single screen. For such sections, after the selected graph length is displayed, the screen is reset and the next part of the profile is displayed.

#### ***2. Run Identification (see Section 2.3.6.2):***

The following procedure should be followed in naming the section number for SPS sections.

- (a) The first two digits identify the state or the province.
- (b) The third digit is the project code.
- (c) The fourth digit is the type of SPS site.
- (d) Last two digits are "XX". If the SPS site is broken into two sections use "X1" and "X2".

Example:      State or province : 26 (Michigan)  
                 SPS project code : A  
                 SPS project type : 3  
                 Identification : 26A3XX

If there is only one SPS section of a given project type in the state, the third digit of the filename will be zero. When saving a header file the same notations are used.

### 3.      *Run Control Method (see Section 2.3.6.5):*

The data acquisition can be terminated by either selecting pendant stop or distance (see Section 2.3.6.5). However, "distance" should be selected as the method to terminate data acquisition. The operator should refer to site layout plans and obtain the length of the SPS test section to be tested. To obtain the length to be profiled, add 200 ft to the distance obtained from the site layout plan. This should ensure that all test sections will be profiled even if there are discrepancies between the layout plans and the sections as-built. After selecting "distance" as the stop method in the Run Control Menu, enter the length to be profiled.

### 2.7.7 *Hardcopy of the Profile*

Only the final screen appearing in the monitor will be printed during testing. For those SPS sections that cannot be profiled on one screen, the following procedure should be used to obtain the entire profile. After each run, enter the Run Replay program of the Main Menu (see Section 2.3.4) and regenerate the profile data at 800 ft intervals and obtain a hardcopy of each screen. By having the profile of the entire test section, spikes or inconsistencies in the data can be observed for the entire run.

### 2.7.8 *Labeling Data Disks*

For ease of file management all data collected at a SPS section should be in a single disk. In some instances a GPS section is profiled together with SPS sections due to the layout of the site. The following procedure should be followed when labeling data disks for SPS test sites.

- LINE 1:      "SPS PROJECT NAME xxxxxx" where xxxxxx is the six character name to describe the SPS test section.
- LINE 2:      If a GPS section is profiled together with a SPS section "Associated GPS ID# xxxxxx" where xxxxxx is the GPS section number. If no GPS section is included in the data, leave a blank line.
- LINE 3:      "Volume x of y" where x is the number of the current disk in the set and y is the total number of disks in the set.
- LINE 4:      "Copy # x" where x is the number, usually 1 to 3.



LINE 5: "Profilometer SN xxx" where xxx is the actual serial number of the Profilometer that tested this section.

LINE 6: "MM/DD/YY" where MM/DD/YY is the month, date and year that the testing was performed.

Example:     SPS Project # 26A3XX  
              Associated GPS ID# 263456  
              Volume 1 of 1  
              Copy 1 of 3  
              Profilometer SN 007  
              Date 08/28/91

This disk contains data for SPS section 26A3XX and GPS Section 263456 collected on August 28, 1991.

## **3. Dipstick Profile Measurements**

### **3.1 Introduction**

The Face Technologies Dipstick is a manually operated device for the collection of precision profile measurements at a rate and accuracy greater than traditional rod and level survey procedures for individual readings. However, multiple readings may contain systematic cumulative errors, which may cause a shift of the true profile. The body of the Dipstick houses an inclinometer (pendulum), LCD panels, and a battery for power supply. The sensor of the Dipstick is mounted in such a manner that its axis and the line passing through the contact points of the footpads are co-planar. The sensor becomes unbalanced as the Dipstick is pivoted from one leg to the other as it is moved down the pavement, causing the display to become blank. After the sensor achieves equilibrium, the difference in elevation between the two points is displayed. The Dipstick is equipped with a choice of hardened steel spike feet or ball-and-swivel footpads. The swivel pads should be used on textured pavements.

Calibration of the Dipstick is fixed during manufacture and cannot be altered by the user. Factory calibration accuracy is stated to be 0.038 mm (0.0015 in.) per reading. The user can verify the calibration against a standard calibration block which is provided with the Dipstick.

### **3.2 Operational Guidelines**

#### ***3.2.1 General Procedures***

Dipstick measurements are to be taken by personnel who have been trained in using the device and are familiar with the procedures described in this manual. The detailed scheduling and traffic control at test sites must be coordinated by the regional coordination office contractor (RCOC). All traffic control activities at test sites will be provided by the state or provincial highway agency.

#### ***3.2.2 SHRP Procedures***

***Maintenance of Records:*** The Dipstick operator is responsible for forwarding all data collected during tests (see forms in Appendix VI). In addition, the operator is also required to forward other records related to Dipstick operation which are described in the section on record keeping to the RCOC.

***Equipment Repairs:*** The RCOC is responsible for ensuring that the SHRP owned equipment is properly maintained. The decisions required for proper maintenance, as well as repair should be made based on the testing schedule and expedited as necessary, to prevent disruption of testing.

**Accidents:** In the event of an accident, the operators will inform the RCOC of the incident as soon as practical. Details of the event shall subsequently be reported in writing to the RCOC to assist in any insurance claim procedures.

### **3.3 Field Testing**

#### **3.3.1 General Background**

The following sequence of field work tasks and requirements provides an overall perspective of the typical work day at a test section.

**Task 1: Personnel Coordination**

- a: Dipstick crew (operator and recorder for manual Dipstick; operator only for auto-read model)
- b: Traffic control crew supplied by the state highway agency (minimum one person or as recommended by the state highway agency)
- c: Other SHRP, State DOT, and RCOC personnel (they are observers and are not required to be present)

**Task 2: Site Inspection**

- a: General pavement condition (within test section limits)
- b: Identify wheel paths

**Task 3: Dipstick Measurements**

- a: Mark wheel paths
- b: Operational checks on Dipstick
- c: Obtain Dipstick measurements
- d: Quality control

**Task 4: Complete the Dipstick Field Activity Report (see forms in Appendix VI)**

On arrival at the site, the Dipstick operator will carefully plan the activities to be conducted at the site to insure the most efficient utilization of time. While many of the activities can only be accomplished by the Dipstick operator and/or recorder, it will be necessary to enlist the assistance of other personnel at the site to mark the wheel paths. In general, arrangements for this assistance should be made in advance.

Assuming that a manual distress survey is also to be performed at a site, traffic control at a typical GPS site should be available for about eight hours. This should provide adequate time for Dipstick measurements in both the wheel paths as well as the manual distress survey to be completed. As far as the Dipstick productivity rate is concerned, experienced operators have been able to obtain 500 readings per hour.

Collecting profile data is the primary responsibility of the Dipstick operator. In order to ensure that the data collected in all of the SHRP's four regions is identical in format, certain guidelines and standards have been established for the data acquisition and handling phase.

### ***3.3.2 Site Inspection and Preparation***

The pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick, as such conditions can affect the profile measurements. Pools of water can possibly damage the electronics in the Dipstick and must be avoided either through adjusting the schedule of profiling trips, or by delaying actual measurements until acceptable conditions exist. If acceptable conditions are present then proceed as follows.

1. Clean both wheel paths of loose stones and debris to prevent slippage of the Dipstick footpads during measurements.
2. Use a chalk line to mark a straight line in each wheel path, 0.8 m (32.5 in.) from the center of the travel lane. The center of the travel lane should be located using the following guidelines.

*Case I:* Where the wheel paths can be easily identified, the center of the travel lane is considered to be midway between the two wheel paths.

*Case II:* Where the wheel paths are not clearly identifiable, but the two lane edges are well defined, the center of the travel lane is considered to be midway between the two lane edges.

*Case III:* Where only one lane edge is well defined, the center of the lane is considered to be 1.8 m (6 ft) from that edge.

If the manual Dipstick is being used, a comment in the data collection sheet should be made on how the center line of the lane was defined. If the auto read Dipstick is used the method of determining the center of the road should be noted in the field notebook. This information will help to collect consistent data in future profile measurements at that section.

3. Lay out and mark straight lines for transverse profile measurements. The lines shall be perpendicular to the edge of the pavement at intervals of 15.25 m (50 ft), starting at Station 0+00 and ending at Station 152+50 (5+00). For GPS sections, eleven lines will be present. The location of lines should be adjusted to avoid raised pavement markings and similar anomalies. The need for and magnitude of such adjustments is to be recorded on the data sheets. Transverse profile measurements are not required for rigid pavements, and in instances where PASCO cross-profile data is available.

### 3.3.3 Dipstick Operation for Longitudinal Profile Measurements

#### 3.3.3.1 Pre-operational Checks on the Dipstick

The checks to be performed on the Dipstick prior to testing are described in this section.

1. Check the condition of footpads and replace if necessary with the extra set in the Dipstick case. Clean and lubricate the ball and socket joints on the footpads to insure smooth pivoting of the instrument. When the joint is dirty, pivoting becomes difficult and slippage of the footpad can occur. A cleaning agent such as WD-40 and a light oil for lubrication will work for the ball and socket joint.
2. Install a fresh set of batteries in the instrument and securely close the battery compartment. Batteries should be changed after 4 hours of usage to insure continuity of measurements. Several sets of rechargeable 9 volt batteries should be kept on hand.
3. Check and if necessary, re-tighten the handle on the instrument.
4. Perform the zero check and the calibration check, which are described next. The Zero and Calibration Check Form should be completed whenever these tests are carried out.

**Zero Check:** A zero verification is performed by this test. This test should be performed on a smooth clean location where the instrument can be properly positioned (the carrying case for the Dipstick, or a flat board will suffice). After positioning the Dipstick draw two circles around the two footpads and note the reading on the display (reading = R1). The instrument should then be rotated 180 degrees and the two footpads placed on the two circles which were drawn earlier. Note the reading obtained (reading = R2). If the readings from the two placements (R1 and R2) add up to within  $\pm 0.001$  the Dipstick has passed the zero check. If the addition of two readings do not fall within these limits, zero adjustment is necessary. The zero adjustment should be performed using the following procedure.

First obtain the average of the two Dipstick readings:

$$e = 0.5 (R1 + R2)$$

Then subtract this value from reading R2 to obtain R2o:

$$R2o = R2 - e$$

Then, with the Dipstick still in the R2 reading position loosen the set screw and adjust the start end adjusting pin up or down so that the display reads R2o. Thereafter, tighten the set screw and rotate the Dipstick back to the R1 reading position and read

the display (reading =  $R_{10}$ ). Now the addition of  $R_{10}$  and  $R_{20}$  should be within tolerance. If this sum is not within tolerance repeat the adjustment procedure until the two readings are within tolerance.

This zero adjustment is the only adjustment the operator is allowed to make on the Dipstick.

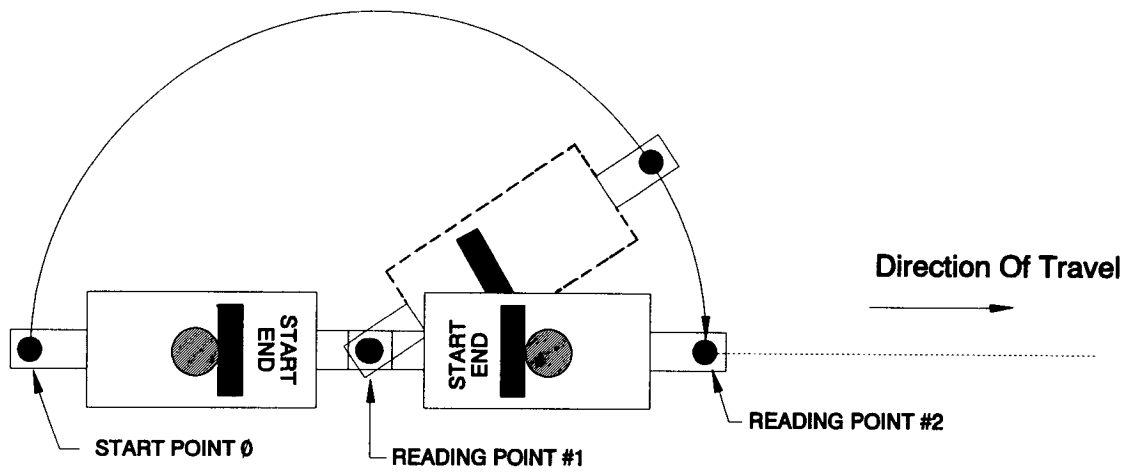
**Calibration Check:** After the zero check and zero adjustments are performed as required, the calibration of the device must be checked. To check the calibration, place the 3.175 mm (0.125 in.) calibration block under one of the Dipstick footpads. The reading displayed, minus 0.125, should equal the previous reading  $\pm 0.003$ . If the answer is not within this tolerance, a SHRP Major Maintenance/Repair Activity Report should be completed and Face Technologies should be contacted through the RCOC to repair the Dipstick.

According to the manufacturer the calibration check is needed only if adjustments were required during the zero check. However, for SHRP related measurements both the zero check and calibration check are required at the beginning and end of data collection. Records of these checks should be noted in the Zero and Calibration Check Form shown in Appendix VI.

### 3.3.3.2 Longitudinal Profile Measurement

To start profile measurements, the Dipstick should be placed on a marked wheel path line at station 0+00 with the start arrow pointed forward. A clockwise rotation as indicated in Figure 3.1 should be used in advancing the device. Although the manufacturer does not prohibit a counterclockwise advance, it is prudent to keep the same motion for all test sections so that any potential errors introduced by the rotational direction are consistent in all Dipstick data. As the Dipstick is walked along the marked wheel path, the readings should be recorded on the Longitudinal Profile Data Collection Form if a manual Dipstick is used. If the auto-read Dipstick is used, the readings are stored in the computer attached to the Dipstick. In this case the operator must use the trigger to instruct the computer to store the reading rather than using the automatic storage scheme, to ensure adequate time for the pendulum to stabilize. Use of the automatic mode, even at the lowest production rate, may not allow adequate time for stabilization, thus introducing possible errors in the data.

Frequently an operator will introduce bias in the readings by leaning the Dipstick handle laterally from a true vertical position during operation. The operator must not apply any lateral pressure on the handle while the reading is taken. Two runs on each wheel path of the SHRP section must be undertaken by the Dipstick operator, consisting of one run up the wheel path and one run back down the same wheel path. This will accomplish a closed loop survey for each wheel path.



**Figure 3.1. Dipstick Measurements**

Minor localized cracks and holes in the pavements as well as open joints should be avoided during the Dipstick profile measurement process (e.g., instances where one footpad sinks into a crack or hole or into an open or faulted joint). Also care must be exercised not to place the footpad partially on top of an opening or very wide crack as this may cause slippage during the next advance motion of the Dipstick. If the use of swivel pads is not feasible for some reason, then the operator should avoid isolated depressions by locating the test point on either side of small cracks or holes. If the crack or hole is too big to avoid in this manner, then most likely it should be measured as part of the surface profile and its presence noted in the comments section of the data sheet.

The Dipstick measurements for each wheel path should be taken continuously. However, if for any reason the operator has to stop measurements (e.g., a sudden heavy storm), the point where the last reading was taken must be clearly marked (draw a circle around the footpad). The operator may continue the Dipstick measurements later from this position after placing a comment on the data collection sheet assuming that this point is clearly identifiable on the pavement. The above procedure is suggested by the manufacturer. However, Dipstick measurements on SHRP sections should not be interrupted unless absolutely necessary.

After the forward and the return run have been completed on one wheel path, the post data collection check and quality control check need to be completed before taking measurements on the other wheel path.

### 3.3.3.3 Post Data Collection Check

To ensure the accuracy of the collected data the operator must conduct the zero and calibration checks outlined above after completing measurements on a wheel path. If the Dipstick fails either of these checks, the data must be considered as suspect. If the Dipstick fails the zero check, repeat the profile measurements after adjusting the Dipstick as noted in point 4 of Section 3.3.3.1. If the Dipstick fails the calibration test, follow the procedure under point 4 in Section 3.3.3.1. If the Dipstick satisfies these checks, proceed with the quality control checks.

### 3.3.3.4 Quality Control Check

Various forms of error may be introduced into the Dipstick measurements including operator bias, footpad slippage, low battery power, and recording errors. A closed loop survey is used to establish the total accumulated error in the profile measurements acquired with the Dipstick. A closed loop survey is accomplished by completing an initial run along one wheel path and a return run along the exact same wheel path (1 closed loop = 2 runs). The final value of the running sum of the two runs should theoretically result in a zero elevation difference. Any difference in elevation that is obtained is assumed to be due to operator error. By dividing the accumulated error by the length of the loop survey, the error per reading can be obtained. The maximum error allowed is 0.076 mm (0.003 in.) per reading, which corresponds to a total elevation difference of 76 mm (3 in.) for a run 305 m (1000 ft) long (152.5 m up and 152.5 m back; 500 ft up and 500 ft back). If the allowable elevation difference is exceeded during a Dipstick measurement of a test section, the section must be



re-tested until acceptable results are obtained.

### ***3.3.4 Dipstick Operation for Transverse Profile Measurements***

#### **3.3.4.1 Operational Checks**

The operator should check the equipment using the procedures described above. The checks would include the zero check as well as the calibration check.

#### **3.3.4.2 Transverse Profile Measurement**

Dipstick transverse profile measurements will be collected at intervals of 15.25 m (50 ft), starting at station 0+00. Elevations for each transverse profile location will be measured from the outside edge of the pavement and should extend over the full lane width, with the actual distance depending on lane width and pavement striping. The starting point should be the junction of the transverse measurement line and the inside edge of the white paint stripe along the outside edge of the lane. If no outside edge stripe is present, then the beginning point shall be either the shoulder-lane joint or a point approximately 0.9 m (3 ft) from the center of the outside wheel path. A comment should be entered in the data sheet on how the starting point was determined. The initial elevation is arbitrarily established as "zero" and the subsequent readings are recorded relative to this benchmark. The combination of these measurements provide a measure of the pavement cross slope.

To begin the transverse profile measurements, the Dipstick is placed at the outside edge of the pavement starting at Station 0+00 with the start arrow pointed towards the pavement centerline (see Figure 3.1). If the manual Dipstick is being used the measurements should be recorded on the Transverse Profile Data Collection Form. If the auto-read Dipstick is used it should be triggered to record the readings. The Dipstick operator should complete two runs per transverse profile of each SHRP section; one run up the transverse line and a return run back along the transverse profile to complete the closed loop survey.

#### **3.3.4.3 Quality Control for Transverse Profile**

The total accumulated error in the transverse profile measurement shall be established by a closed loop survey. The forward and return run along a transverse section is utilized to compute this error. The maximum allowable error for the transverse profile measurements is 0.076 mm per reading, or 1.8 mm total (0.003 in. per reading, or 0.072 in. total) for a transverse run 7.32 m (24 ft) long (3.66 m up and 3.66 m back; 12 ft up and 12 ft back). For a transverse run 9.76 m (32 ft) long (4.88 m up and 4.88 m back; 16 ft up and 16 ft back), the maximum allowable total error is 2.4 mm (0.096 in.).

### ***3.3.5 Data Backup***

The importance of safeguarding the Dipstick data cannot be overstated. Back-up copies of the Dipstick data must be made without exception after completion of data collection for each

test section. Whether the data is recorded on the forms given in Appendix VI, or on electronic media, copies should be made at the earliest time possible.

A minimum of two complete copies shall be made of all Dipstick data. One copy will be transmitted by mail to the regional coordination office while the second will be retained by the operator in case the first copy is lost in the mail.

### **3.4 Calibration**

#### ***3.4.1 General Background***

Internal calibration of the Dipstick is fixed during manufacture and cannot be altered by the user. However, to ensure that the instrument is operating properly the calibration can be checked using the zero check and the calibration check described under *Pre-operational Checks on the Dipstick*. If the Dipstick fails the calibration test it should be returned to the manufacturer for repair.

The gage block used during the calibration check should be calibrated to an accuracy of  $3.175 \pm 0.025$  mm ( $0.125 \pm 0.001$  in.) using a local calibration laboratory or a calibration micrometer to ensure the minimum 4:1 ratio of accuracy of gage blocks to the Dipstick. The gage block should be recalibrated once every year, or more frequently, depending on (1) presence of oxidation, (2) evidence of erosion, and (3) possible damage caused by accidental mishandling in the field.

If the calibration block (gage block) thickness is not within  $3.175 \pm 0.025$  mm ( $0.125 \pm 0.001$  in.), all data collected since the last check of the block are suspect and may have to be disregarded.

#### ***3.4.2 Calibration Frequency***

The zero check and the calibration check should be conducted by the operator prior to and after any Dipstick measurements. If the Dipstick fails the calibration test, the approval from an RCOC engineer is required before shipping the equipment to the manufacturer.

### **3.5 Equipment Maintenance and Repair**

#### ***3.5.1 General Background***

Scheduled preventive maintenance will serve as a means of ensuring proper operation of the equipment as well as identifying potential problems. Timely identification of problems will help to avoid costly delays or incomplete data which could result from on site equipment malfunction. The time constraints on the profile testing program require that maintenance activities be performed prior to mobilization for testing. During testing it is necessary that the operator be constantly aware of the proper functioning of the equipment. There will be little time to accomplish more than the required initial checks at the site in preparation for

the test day. Therefore, preventive maintenance must be performed as a routine function at the end of each test/travel day and on days when no other work is scheduled.

Minimizing the rate of equipment deterioration is the responsibility of the RCOC and individual operators. Specific, detailed maintenance procedures are contained in the manuals provided with each individual piece of equipment, and the operator must become intimately familiar with the maintenance recommendations contained in all equipment manuals. This section is intended to reinforce the concept of maximum equipment dependability, which is critical to the effectiveness of the LTPP program.

It is not the intention of this guide to supersede manufacturers' minimum services and service intervals, but to provide supplementary service requirements. Where there is a conflict between this guide and the manufacturers' instructions, the more stringent requirements should be followed.

### ***3.5.2 Routine Maintenance***

Routine maintenance includes those functions which can be easily performed by the operator with minimal disassembly of a particular device. Routine maintenance for the Dipstick includes the cleaning and lubrication of the ball and socket joints on the footpads, replacement of the batteries and cleaning of the battery contacts. These items are basic and easily performed preventive measures and should always be completed prior to operation of the equipment.

The following list of pre-operation preventive maintenance items is not complete, but is intended to show the extent and detail required before the operation checks are performed. This list of items is not to supersede manufacturers' minimum requirements for warranty compliance.

1. *Exterior:* Check general appearance, glass display (should be clean), ball and socket joint for the footpads (should be properly lubricated).
2. *Accessories:* Be sure adequate supplies of consumables are on hand (e.g., batteries, grease, WD-40).

In the Dipstick Field Activity Report the first line of information following the section identification data is an acknowledgement that the pre-operation checks were properly performed.

### ***3.5.3 Scheduled Major Maintenance***

Scheduled major preventive services shall include much more than the routine checks and will require some disassembly of the equipment by personnel with technical capabilities beyond the skill of the operators or RCOC staff. The SHRP Major Maintenance/Repair Report should be used by the operator to report the performance of necessary services. This form will also serve to inform the RCOC of the condition of the Dipstick on a regular basis.

Items such as battery connector replacement would fall into the major maintenance category. The appropriate service intervals are outlined in the equipment manufacturer's manual.

### ***3.5.4 Equipment Problems and Repair***

Regardless of the quality of the preventive program there will probably be equipment failures during the LTPP program. When these occur it is extremely important that repairs or replacement of items be accomplished in a timely fashion. During periods when there is no scheduled testing, these problems are easily handled. However, if they occur during mobilization or while on site, significant problems in scheduling and coordination could develop. To help minimize the impact of equipment problems it is essential that the operator immediately notify the RCOC and any other agencies or individuals as necessary. The responsibility for equipment maintenance and repair activity rests with each RCOC. However, the RCOC should keep LTPP staff informed of any major problems concerning the equipment. When repairs are necessary and must be performed by an outside agency, the operator will report this information on the SHRP Major Maintenance Report form as an unscheduled maintenance activity. Details of the circumstances during field testing related to this maintenance activity should be noted on the daily activity report. Minor repairs performed by the operator at times other than during testing should be recorded on a daily activity report that clearly states no testing was performed. In this case, no reference information (section number, etc.) will be entered.

## **3.6 Record Keeping**

The Dipstick operator will be responsible for maintaining the following forms and records:

1. Dipstick Field Activity Report
2. Major Maintenance/Repair Report
3. Zero and Calibration Check Form

All of these forms are included in Appendix VI.

Each of these records shall be kept in up-to-date files by each RCOC with one complete set kept on file at the regional office. A description of each of these forms follows.

### ***3.6.1 Dipstick Field Activity Report***

The Dipstick Field Activity Report is an document prepared by the Dipstick operator which includes a commentary of all activities associated with profile measurements. The information to be noted in this form includes: the section information, time to complete all measurements, any downtime, information related to productivity, any factors which might affect the collected test data and names and organizations of other personnel present at the site. The names of these personnel would be invaluable if an accident occurs at the test site. A space is provided in this form for the operator's acknowledgment that pre-operation checks were conducted prior to any Dipstick testing. The operator should fill out a Dipstick Field Activity Report at every section where a Dipstick test is conducted. In addition this form

should be completed whenever the operator performs maintenance on the Dipstick. The original of this report should be kept by the operator with a copy forwarded to the RCOC.

### ***3.6.2 SHRP Major Maintenance/Repair Report***

When any major maintenance or repair must be performed by an outside agency, the SHRP Major Maintenance/Repair Activity Report must be filed. Routine maintenance (pre-operation checks) and minor, operator performed repairs should be reported on the Field Activity Report.

### ***3.6.3 Zero and Calibration Check Form***

This form should be completed whenever the zero and calibration checks are carried out.

## 4. Profile Measurements Using the Rod and Level

### 4.1 Introduction

The rod and level can be used to accurately measure the profile of a pavement. The profile data can be used to evaluate the roughness of the pavement by computing a roughness index such as International Roughness Index (IRI) or to evaluate effects such as frost heave or swelling of soils. In computing roughness indices, only the relative elevations and not the absolute elevations are needed. The guidelines in this section can be applied to conventional survey equipment such as an optical level and graduated staff, which require the readings to be manually recorded, as well as automated equipment which is capable of automatically storing the measured data. Forms for recording rod and level measurements are given in Appendix VII.

### 4.2 Operational Guidelines

#### 4.2.1 General Procedures

The detailed scheduling and traffic control at the test sites must be coordinated by the RCOC. However, all traffic control activities at test sites will be performed by personnel from either the state or provincial highway agency.

#### 4.2.2 Equipment Requirements

The rod and level used in routine surveying and road construction will generally not have the resolution needed for pavement profile measurements. For pavement profile measurements precision levelling instruments are required. The instrument used for profile measurement should satisfy the resolution criteria given in the following table, which was obtained from the ASTM Standard Test Method for Measuring Road Roughness by Static Level Method (2).

IRI Range				Resolution
0	<=	IRI	<30 in/mile (0 <=IRI < 0.47 m/km)	0.005 in (0.13 mm)
30	<=	IRI	<63 in/mile (0.47 <=IRI < 1.00 m/km)	0.01 in (0.25 mm)
63	<=	IRI	<190 in/mile (1.00 <=IRI < 3.00 m/km)	0.02 in (0.51 mm)
190	<=	IRI	<317 in/mile (3.00 <=IRI < 5.00 m/km)	0.04 in (1.02 mm)
317	<=	IRI	<444 in/mile (5.00 <=IRI < 7.00 m/km)	0.06 in (1.52 mm)
IRI	> 444		in/mile (IRI > 7.00 m/km)	0.08 in (2.03 mm)

The rod used should be equipped with a bubble level so that it can be held vertical accurately. A suitable base must be selected for the rod in order to reduce the sensitivity to small variations in rod placement. For smooth-textured pavements any type of base is suitable. For textured surfaces, a circular pad with a diameter of at least 0.8 in. (2.0 cm) is recommended (2). As only relative elevations are required for computing roughness indices no correction is required for attaching a pad to the bottom of the rod.

### **4.2.3 SHRP Procedures**

**Maintenance of Records:** The instrument operator/record keeper is responsible for forwarding all data collected during tests to the Regional Coordinating Office Contractor.

**Accidents:** Insurance coverage for all persons involved in the survey should be maintained by the RCOC. The operator will inform the RCOC of the incident as soon as practical after the accident. Details of the event shall subsequently be reported in writing to the RCOC to assist in any insurance claim procedures. SHRP headquarters should be notified of the accident as soon as possible by the RCOC.

## **4.3 Field Testing**

### **4.3.1 General Background**

The following sequence of field work tasks are required.

**Task 1: Personnel Coordination**

- a: Personnel for rod and level survey.
- b: Traffic control crew supplied by the state highway agency (minimum one person or as recommended by the state highway agency)
- c: Other SHRP, state DOT, and RCOC personnel (they are observers and are not required to be present)

**Task 2: Site Inspection**

- a: General pavement condition (within test section limits)
- b: Identify wheel paths

**Task 3: Rod and Level measurements**

- a: Mark wheel paths
- b: Obtain rod and level readings

To measure the pavement profile using the rod and level, two persons are generally needed. One person is needed to hold the rod (rod-person) and another to operate the level and take readings (instrument operator). If the level is not capable of automatically recording the readings, an additional person (record keeper) to record the readings will make the process quicker. An experienced crew of three would require less than 10 seconds to obtain one reading (2). This involves the positioning of the rod by the rod-person, reading the level by the instrument operator and the recording of the measurements by the record keeper.

### 4.3.2 Site Inspection and Preparation

The two wheel paths in the outside travel lane should be marked using the following procedure.

1. Clean loose stones and debris from both wheel paths to prevent slippage of the rod during measurements.
2. Use a chalk line to mark a straight line in each wheel path. This line should be 32.5 in. (0.8 m) from the center of the travel lane. The center of the travel lane should be located using the following guidelines.

*Case I:* Where the wheel paths can be easily identified, the center of the travel lane is considered to be midway between the two wheel paths.

*Case II:* Where the wheel paths are not clearly identifiable, but the two lane edges are well-defined, the center of the travel lane is considered to be midway between the two lane edges.

*Case III:* Where only one lane edge is well defined, the center of the travel lane is considered to be 6 ft (1.8 m) from the edge.

The method by which the wheel paths were located should be noted in the comments field of the Rod and Level Data Collection Form (see Appendix VII). This will help in locating the wheel paths used for profile measurements at a future date.

Measurements have to be taken along the wheel paths at 1 ft (0.3 m) intervals. The locations at which readings are to be taken can be determined by either of the following methods.

1. Lay a surveyor's tape along the chalk line and mark distances on the pavement at 1 ft (0.3 m) intervals using a suitable marker. Markings have to be made along the entire length of the section on both wheel paths.
2. Place a surveyor's tape on the wheel path with the zero of the tape corresponding to the start of the section. Secure the both ends of the tape with a weight or adhesive tape. Distances along the section can be referenced from the tape. After the distance corresponding to the length of the tape is levelled, the tape will have to be repositioned.

### 4.3.3 Longitudinal Profile Measurements

The first reading taken after the level is set up is referred to as a backsight while the last reading taken at that setup before the level is moved is referred to as a foresight. Other readings taken in-between a backsight and a foresight are referred to as intermediate sights. The procedure to be followed for measuring the longitudinal profile is described next.



1. Complete the required information in the Rod and Level Data Collection Form (Appendix VII).
2. Set up the level at a suitable location, taking into account the range of the level. With some instruments it might be possible to cover the entire test length from one instrument set-up, located near the center of the test section. The level should be placed where it will not be disturbed due to passing traffic. In addition, it should be placed where it will not settle. When setting the tripod, set it as low as practical to reduce the error caused by the rod not being exactly vertical. Thereafter, level the instrument using the leveling screws.
3. The rod person should place the rod at the zero position of the section. Use the bubble level attached to the rod as a reference to hold the rod vertical. Once the rod is held vertical, the rod person should signal to the instrument operator to take a reading. If the readings are recorded manually by a third crew member, the instrument operator should call out the reading to the record keeper. The readings should be recorded in the form shown in Appendix VII. If an automated system is being used the instrument operator should make sure that the reading is saved.
4. Next, the rod person should place the rod 1 ft (0.3 m) away from the initial reading, and a new reading should be recorded. This process should be continued until either the entire test section is surveyed, or the horizontal range or the vertical range of the level is exceeded. The horizontal range of the level is exceeded if the distance between the level and the rod is too short or too long to focus properly. The vertical range of the level is exceeded if the rod cannot be read due to the slope of the road. When the range of the level is exceeded, the level has to be relocated.
5. (a) Range of the Level is Exceeded:

If the range of the level is exceeded the instrument has to be relocated. Mark the location at which the rod is to be held for the last reading. This position is called a *pivot point*. Place the rod at the location where the first reading was taken with the current setup of the level, and take a reading. Compare this reading with the first reading that was taken at this location. If they do not agree within the resolution of the instrument, all readings taken from the current position of the level have to be repeated.

If the readings agree, place the rod on the pivot point and take the last reading from the current set up of the instrument (foresight). Then set up the instrument at a new location. Place the rod at the pivot point and take a reading (backsight). Continue the levelling process as before, taking readings at intervals of 1 ft (0.3 m). If the instrument has to be repositioned again, follow the procedure described earlier.

(b) End of the Test Section is Reached: The following two cases are possible.

1. Entire Survey Performed from One Instrument Set Up: Place the rod at the zero position (the point from which the survey was initially started) and take a reading. This reading should agree with the very first reading taken at this location at the start of the survey within the resolution of the instrument. If the readings do not agree, the profile measurement has to be repeated.
2. Instrument Repositioned During Survey: Place the rod at the last pivot point and take a reading. This reading has to agree with the earlier reading taken at this position within the resolution of the instrument. If they do not agree, the profile has to be measured again from the last pivot point to the end of the section.

The measurement of pavement profiles using the rod and level is labor intensive and time consuming. Therefore, it is advisable to check the accuracy of the measured data at regular intervals. This can be performed by establishing a set of control points along the wheel path, for example at 100 foot (30.5 m) intervals starting from the beginning of the section. After leveling a distance of 100 feet (30.5 m), the rod has to be placed at the previous control point and another reading taken. This reading has to agree with the previous reading taken at this control point within the resolution of the instrument. If the readings do not agree, the length between the control points has to be measured again. This procedure can be used if the instrument setup is not changed between the two control points being considered. If the instrument setup is changed between two control points, the above procedure can be still applied, treating the pivot point as a control point.

#### *4.3.4 Factors to be Considered*

The following factors have to be considered when conducting profile measurements with the rod and level.

1. If the level is sensitive to temperature variations, it might need to be covered with an umbrella to protect it from direct sunlight.
2. During windy conditions, profile measurements should be avoided, as movement of the level could occur.
3. If the level has to be set up at more than one position during profile measurements, make the length to backsights and foresights equal. This will eliminate errors due to curvature and refraction at turning points.

### 4.3.5 Profile Computation

During field profile measurements, the crew is only expected to record the readings of the level using the procedures described in Section 4.3.3. The computation of the elevation profile from this data will be done in the office. This section will briefly describe how the data recorded in the field is used to obtain the longitudinal profile of the pavement.

For profile computations, the elevation of the location where the first reading (first backsight) was measured is needed. However, as only relative elevations are needed to compute roughness indices (such as IRI), an arbitrary value can be selected for the elevation of this point. The relative elevation of any point measured from the initial instrument setup can be obtained from the following equations.

$$\text{Instrument Height (IS)} = \text{BM} + \text{RR1} \quad (4.1)$$

$$\text{Relative Elevation of a Point} = \text{IS} - \text{RR} \quad (4.2)$$

where,

IS	=	Initial instrument height
BM	=	Elevation of point where the first backsight was taken (assume any value, e.g., 100 ft (30.5 m))
RR1	=	Rod reading at first backsight
RR	=	Rod reading at any point from the initial instrument setup

Once the position of the level is changed, the instrument height will also change. The new instrument height can be obtained from the following equation.

$$\text{Nht} = \text{Oht} + \text{BS} - \text{FS} \quad (4.3)$$

where,

Nht	=	New instrument height
Oht	=	Old instrument height
BS	=	Backsight at pivot point
FS	=	Foresight at pivot point

The relative elevation of points measured from this new instrument location can be determined by using Equation 4.2 and using the new instrument height as the instrument height.

### 4.3.6 Quality Control

The quality control applied to profile data from the rod and level can be classified as field quality control and office quality control.

**Field Quality Control:** This check ensures that no movement of the level took place during the current setup of the level. This has to be verified every time before the instrument is

moved and when the end of the test section is reached. This check is performed by keeping the rod at the location at which the first reading was taken with the current instrument setup and again taking a reading. Both readings have to agree within the resolution of the instrument. This check can also be performed at regular intervals by establishing a set of control points as described in Section 4.3.3.

**Office Quality Control:** The computation of the elevation profile from the raw field data should be performed in the office using a computer. Using the computer will prevent mathematical errors during computation. The quality control used in the field will not detect an incorrect reading being recorded at an intermediate location. However, during processing of raw data, erroneous readings can be detected by plotting the elevation profile.

## **4.4 Calibration and Adjustments**

The user manual of the level should be consulted on how to perform adjustments of the instrument. Different makes and models of levels will require different adjustments to be performed. The following are some common adjustments which are required in levels in order to obtain accurate measurements. The user manual of the level should be consulted to determine if the following adjustments are needed for the level being used, and if so, how to perform the specific adjustment.

1. **Make Axis of Level Bubble Perpendicular to Vertical Axis:** After setting up the level, center the bubble. Move the telescope 180 degrees about the vertical axis. If the bubble moves, the instrument needs adjustment.
2. **Adjust Horizontal Cross Hairs:** This adjustment will ensure that the horizontal cross hairs are truly horizontal when the instrument is leveled.
3. **Adjust Line of Sight:** This adjustment will make the axis of sight perpendicular to the vertical axis and also make it parallel to the axis of the level. The method of adjustment for this error is commonly referred to as the two-peg method.

The rod has to be checked to see the accuracy of the markings. A standardized tape should be used for this.

## **4.5 Equipment Maintenance**

Shock-proof packaging should be used when transporting the instrument. After completing a profile measurement, always clean the instrument. Before cleaning the lenses, blow the dust off the lenses. Clean the lenses using a soft cloth. The lenses should not be touched with the fingers. If the instrument becomes wet in the field, make sure that it is completely dry before packing. The tripod should be inspected regularly to ensure that the connections are not loose.

## **4.6 Record Keeping**

The Rod and Level Data Collection Form (see Appendix VII) should be used to record readings when profile measurements are performed using the rod and level. In addition, a comment should be made on this form as to how the wheel paths were located. All items in this form should be completed by the record keeper. If only two persons are conducting the survey, the instrument operator should complete the form. Even when an automated instrument which is capable of saving the data is used, the location information in this form should be completed.

The operator should forward a copy of the collected data to the RCOC. If an automated unit is used, a backup copy of the data should be made after that data is downloaded to a computer.

## **References**

1. Profscan V1.4 User Documentation. Pavement Management Systems Limited, Amherst, New York, 1992.
2. Standard Test Method for Measuring Road Roughness by Static Level Method. Designation E 1364-90, American Society of Testing and Materials, Philadelphia, Pennsylvania, 1990.
3. Road Profilometer Model 690 DNC User's Manual. K.J. Law Engineers Inc., Novi, Michigan, April 1989.
4. Dipstick Manual. Face Technologies, Norfolk, Virginia.

## **Appendix I. Profscan Manual**

## **Appendix I: Profscan Manual**

### **I.1 Introduction**

PROFSCAN is part of the PROQUAL software which was written in the FoxPro<sup>®</sup> dialect of the dBase language. It is distributed as a runtime version which eliminates the need to purchase the FoxPro software package. The program has been compiled from the FoxPro Version 2.0 software. It also utilizes a graphic kernel, dGE, to display the Profilometer measurements.

PROFSCAN is to be used by the profilometer operator to survey FHWA-LTPP sites. Its primary purpose is to determine whether additional runs should be made over a section of pavement. This decision is based on a set of statistical summaries which are to be used as a guide by the operator to assess the validity of the runs.

Although care has been taken to make the program as "user friendly, intelligent and automatic" as possible, a review of the current PC system configurations may be required. Beta testing has been completed on various PCs (XT, 286, 386, 486) including the Regional Coordination Office (RCO) computers. If set-up assistance is required and/or comments exist on PROFSCAN, please contact the LTPP Division of Federal Highway Administration.

This document will explain how to install and use the software. The operator should have a good working knowledge of IBM/MS DOS.

### **I.2 New to Version 1.4**

After installing the new software over a previously existing \PROF directory, the HISTORY.\* files that are currently present will not be emptied and will still have all the history data. If empty HISTORY.\* files are needed, they can be found on the same installation diskette under a HISTORY subdirectory. Simply copy the files in this subdirectory to the \PROF directory after making sure that a backup of the \PROF\HISTORY.\* files has been made.

The history file can now be accessed by using CTRL+H while in the PROF program. Files can be edited and runs deleted by using CTRL+T to tag these runs. CTRL+W will save and exit the history file while automatically deleting all the tagged records.

If the hard disk is partitioned or if more than one hard disk or external hard drives exist, then the operator has the option of placing the software on one drive and the data on another drive or drives. To accomplish this, it is necessary to edit the PATH and RESOURCE lines of the CONFIG.FP file in the \PROF directory to define the drive specification. For example, if the software is on drive E:, then the PATH and RESOURCE lines of the CONFIG.FP file should say:

```
PATH = E:\PROF
RESOURCE = E:\PROF\PROFUSER
```



The Profilometer serial number should now be entered in the Analyze/Parameters screen from where it will be loaded to the Regional Information Management System (RIMS) data files when created.

When archiving the data to floppy diskette using the Backup option of the menu, a formatted disk is required. The software prompts the user to view the list of files on the backup diskette, allowing the option to erase any files on the diskette and resume the backup or abort the process if the listed files are needed. Users also can make a directory or change to an existing directory on the floppy for the backup files. This can be useful when the user needs to backup more than one site to the same floppy, but in different directories.

For the purpose of testing WIM sites with the same file name as the GPS site, the software was developed to incorporate alpha characters in the extension of the binary file. The letter "M" is equivalent to one (1) and "N" to two (2), O-3, P-4, Q-5, R-6, S-7, T-8 and finally to the letter "U" which is equivalent to nine (9). Thus, five runs on a WIM site tested in May 1992 should have binary files \*.E2M to \*.E2Q. When starting PROFSCAN a subsection will automatically be created with the letter "W" added to the existing section number. The study column will have the "W" character which will define the section as a WIM site and all the reports will indicate this.

When SHRPRA is activated on the binary files and the program is adding a header record, it will check for the surface material starting with A- for asphalt cement concrete or P- for portland cement concrete. If they do not exist, an "error" message will be flashed to the screen. The user will be prompted if a printout of the error is desired. This is an addition to the previous checks for the sample interval to be 6 inches, wave filter to be 300 feet and wave initialization disabled.

### **I.3 System Requirements**

The following lists the minimum hardware configuration required to run the program:

- AT compatible or better (386, 486)
- DOS 3.x or higher
- 640 K RAM
- 40 Mb hard disk
- 3½" 1.44 Mb floppy disk drive
- graphic card and monitor

The performance of the software could be greatly improved if the following hardware is available:

- a math coprocessor
- expanded memory
- color graphic card and monitor (EGA, VGA)
- dot matrix or laser printer

**NOTE:** The two supported printer types are Epson/IBM Graphics Printers and HP Laserjet II and Compatibles.

## **I.4 Installing the Program**

The software comes on one 3½ in. 1.44 Mb floppy disk and must be transferred to a hard disk on which no subdirectory of the root is called "PROF". If there is an existing \PROF directory on the target hard disk, a backup of the \PROF\HISTORY.\* files prior to this installation should be made. Copying the HISTORY.\* files to a floppy disk will accomplish this. This installation should not affect the HISTORY.\* files and the history data will still be present. If empty HISTORY.\* files are needed, then copying all the files in a HISTORY subdirectory on the same installation disk to the \PROF directory will suffice. This will provide blank history files in the \PROF directory.

The installation can be started by changing the logged drive to that of the floppy disk drive (assuming this drive is called B:), then typing:

INSTALL D: [RETURN]

where D is the target hard disk drive, or substitute the appropriate drive letter as required. The installation will then proceed to unpack the files from B: to a D:\PROF directory on the root of the D hard disk. Finish this task before proceeding.

## **I.5 Setting the DOS Environment**

### ***I.5.1 Path***

Previous versions of PROFSCAN required that the DOS environment variable PATH (found in the AUTOEXEC.BAT) be such that the \PROF directory be included. In most cases this is still a necessity, and it is essential that the programs provided on the distribution disk are installed to a \PROF directory on the hard disk. The installation will automatically do so. When the \PROF directory is included in the PATH, the user will have the advantage of starting the program from any drive and any directory or subdirectory. The option of putting the \PROF directory on one drive and the data on another drive or drives also exists. If this is done, then the CONFIG.FP file in the \PROF directory should be edited to include the drive, where the \PROF is located, to the PATH and RESOURCE lines.

### ***I.5.2 Files***

It is essential to set the FILES parameter of the CONFIG.SYS to at least 30. Encountering a "Too many files open" error message creates the need to either increase this parameter or remove any memory resident programs.

**NOTE:** If these parameters are changed, it is necessary to reboot the computer to ensure that the changes take effect. Refer to the *DOS User Manual* for further details.

## **I.6 Setting up the Data**

### ***I.6.1 File Naming Conventions***

It is necessary to name the profilometer files according to the guidelines defined in Chapter 2, Section 2.2.5. In particular, the first two digits of each section number must be valid state codes in order for the software to function correctly. This is also necessary when generating section numbers for demonstration purposes or comparative studies. Failure to adhere to these file naming conventions could produce errors and may even hang up the computer.

The history file stores the summary results by STATE/PROVINCE name, SECTION number, and SUBSECTION number if defined. In order for the history to be updated, the same naming convention must be used for all subsequent data collection. For example, if GPS 511023 was collected as part of SPS 51A300, the history data would be stored under Virginia, 511023 and 51A300. For future data collection on GPS 511023, it will be necessary to use the SPS filename and GPS section number if the history file is to be updated.

### ***I.6.2 File Location***

Organize the profilometer data files into subdirectories under \PROF. For example, New York sites could be stored in a subdirectory under \PROF called NY. Under NY GPS, WIM and SPS subdirectories should exist. This is especially important now since profilometer data will be collected from WIM sites at least once every two years and the WIM sites will use the same name as the GPS section closest to the WIM location. The profilometer files (\*.HDR and \*.C#?) should then be moved into the \PROF\NY\GPS path.

When using the same file/section name, care must be taken to set up separate directories for transfer and analysis of data to avoid over-writing files. If there is more than one set of data for a section, then separate directories (ie directories for Rd1, Rd2, etc.) should be made.

NOTE: In addition, the names of subdirectories must match those of the regional office. This will ensure that any archived files from the profilometer will automatically be located in the correct subdirectory on the regional office computer when the restore is made (ie. there must be identical directory trees on both computers).

## **I.7 Starting PROFSCAN**

To start the program, it is necessary to be positioned in the \PROF directory and then type:

prof [RETURN]

## **I.8 The Main Menu**

A Main Menu will appear across the top of the screen with the 'System' 'Profscan', 'Restore'

and 'Quit' options being the only four user selectable options available. Use 'System' to get system information and some utilities and 'Quit' to return to the DOS prompt.

This version of the software can be most effectively operated with a mouse, which provides quick access to screens and menu options. If a mouse is not available, the ALT key is the key used most often. With this key, one can move between menu options with the arrow keys or just hold the ALT key and press any hot key of each option: ALT+Y will activate the System option, ALT+S will activate the Profscan option, ALT+R will activate the Restore option, ALT+Q will activate the Quit option, and ALT+X will return you to the DOS prompt. Refer to Appendix II for an explanation of how to make menu selections and how to use the keyboard to manipulate windows.

Select Profscan to proceed to the PROFSCAN Menu. After being asked to identify the location of the data files, highlight the corresponding directory and press [RETURN]. Next, select a section by highlighting its header file (\*.HDR) on the list that appears; in most instances, there will be only one to choose from. The program will now convert the profilometer files to ASCII format (via SHRPR.A.EXE) and then load them into data base files.

PROFSCAN will automatically repeat this operation for all profilometer files corresponding to run numbers in the range one to nine, for GPS/SPS sites, or M to U, for WIM sites, inclusive. Once done, this process will not repeat unless:

- (a) more runs are added to the data directory in which case it will convert and load only the newer files. These must be identified by a run number greater than the last run number made over the section and less than or equal to nine, for GPS/SPS sites, or a run letter following the last run letter used but not greater than the letter U, for WIM sites, or
- (b) deletion of all files in the data directory, and replacing most of them with new profilometer data, is desired.

## **I.9 The Profscan Menu**

The following options are available for selection from the Profscan Menu and are subsequently explained:

<u>S</u> ystem	- Provides system information and some utilities
<u>A</u> alyze	- Determines if more runs are necessary
<u>D</u> ata	- Allows viewing of the header data and plotting the profiles
<u>R</u> eport	- Produces analysis results
<u>B</u> ackup	- Archives the dataset for office use
<u>W</u> indow	- Allows manipulation of the windows
<u>E</u> dit	- Assists in editing files
<u>M</u> ain	- Reverts back to the Main Menu to Quit the program

## **I.10 Analyze**

The Analyze option allows Scanning the Event Marks, Defining the Limits, setting up analysis Parameters and finally, calculating the International Roughness Index (IRI) values for the section.

### ***I.10.1 Subsections***

The primary use of this option is to 'break out' SPS sections from profilometer runs in which the individual SPS sites were run consecutively but must be analyzed separately.

Use of the Scan Event Marks allows viewing a list of event marks. This is useful when trying to locate the beginning station of each SPS. One must select a run and then view the event marks.

Define SPS Limits allows definition of the starting and ending station for each SPS in the continuous run. The section header must be provided first in order to proceed with this option.

The Study field is used to identify the site as a General Pavement Study (GPS), Specific Pavement Study (SPS), both (GPS and SPS) or a Weigh in Motion (WIM) site. This is accomplished by entering G, S, B or W respectively. Using a Y in the Include ? column instructs the program to analyze that particular length of pavement. By default, the entire run is set to be analyzed and is defined by a zero start station and an ending station that is equal to the length of the run. Refer to *Adding a new SPS* at the end of this document for more information.

### ***I.10.2 Parameters***

The user selectable parameters which control the calculation of IRI values are shown in Figure I.1. These parameters can be modified at any time prior to selecting the IRI option. Caution is required when changing the parameters. If it is not known how the parameters are used in the analysis, it is suggested that they be left at their current setting or use the suggested values.

The serial numbers for the K.J. Law Profilometer and Face Technologies Dipstick® should be entered by each region. These numbers will be loaded to the RIMS files when they are created.

- i) **Spike Threshold Value** - defines a spike condition. When two consecutive elevations have a difference in excess of this value, and the next elevation is such that a peak is produced, the program will detect a spike. Spike conditions are logged to a file (extension \*.SPI) for review.

Suggested Value: 0.10 in.

System      Analyze      Data   Report      Backup      Window      Edit   Main

[ Analysis Parameters ]

Profilometer Serial No.:	SN007	
Dipstick Serial Number:	30024	
Spike threshold:	0.10	
Summary Interval:	100	
Seed:	[X] 36ft into run	
	[X] User selectable runs	
% Tolerance on mean:	1.0	
% Tolerance on Standard Deviation:	2.0	
Mays Coefficients:		
First	Second	Third
-20	23	58
<< OK >>		

**Figure I.1. The Analysis Parameters**

ii) **Summary Interval** - defines an interval at which IRI values are summarized and reported. Use a value of zero (0) to report IRI at the end of the run.

**Suggested Value:** 100 ft.

iii) **Seed (36 ft into run)** - locates a seed elevation at 36 ft from the beginning of the run to start the recursive IRI calculation. Set to Y if the program is to do so, otherwise use N and enter a distance.

**Suggested Setting:** Y.

iv) **User Selectable Runs** - allows you to manually remove runs from the statistical analysis. Refer to Summary under REPORT for more information.

**Suggested Setting:** Y.

v) **% Tolerance on Mean** - defines, as a percentage of the mean IRI, the maximum that the IRI of a run can deviate from the mean IRI. The latter is determined on runs identified from the user selected runs. Also refer to IRI below.

**Suggested Value:** 1.0

vi) **% Tolerance of Standard Deviation** - defines, as a percentage of the mean IRI, the maximum tolerable standard deviation of IRI from all runs identified in the user selected runs.

**Suggested Value:** 2.0

vii) **Mays Coefficients** - defines the three coefficients used in the relationship to estimate Mays Output from RMSVA at 4 and 16 ft.

**Suggested Values:** -20, 23 and 58

### ***1.10.3 IRI***

Upon selecting IRI, PROFSCAN will prompt the user for a section to be analyzed. Then the IRI analysis will start and sequentially process all profilometer runs on the section that it had detected and converted to a database file. It will utilize the parameter settings (described under Parameters above) throughout the analysis.

If any of the runs were already processed and the results are in the HISTORY file, then the program will ask the user, if it is necessary to repeat the IRI analysis. If Yes is chosen, it will repeat it, if No is chosen, it will move to the next run. It is necessary to remember that the analysis is repeated if any changes are made to the data by logically deleting any runs.

As the calculations proceed, the run's header information and the IRI values in intervals as specified in the Parameters described above will be shown. In addition, if spike conditions are detected, the user will be notified of its location on the screen as well as in the form of a report (extension SPI). After analyzing the final run, the program will generate some statistics on the IRI values including the mean, standard deviation and coefficient of variation. These values are then used to determine if the criteria (of five (5) runs with at least three (3) within the mean ?% and whose standard deviation does not exceed ?% of the mean where ? is user specified as described above) have been met. The results of the test are displayed on the screen.

To abort the analysis of a run, type [ESC]. The user will be asked to proceed with the next run over the section or to abort the analysis completely.

NOTE: An aborted analysis will usually produce incorrect summary statistics. To obtain correct results, the program must be allowed to run completely through the data!

## **I.11 Data**

The Data option will allow you to view and edit the information contained in the header file, print the headers of all the runs, or view the elevations in a graphical format. Use the <Next>, <Prior>, <First>, <Last> options to move to different headers of different runs on the section. Most of the information displayed here are editable using the <Edit> option. The <Print> option is used to print the headers of all the runs. This is the Default Button of this screen and just like any other Default Button with double angle brackets, it can be executed using the CTRL+ENTER keys together.

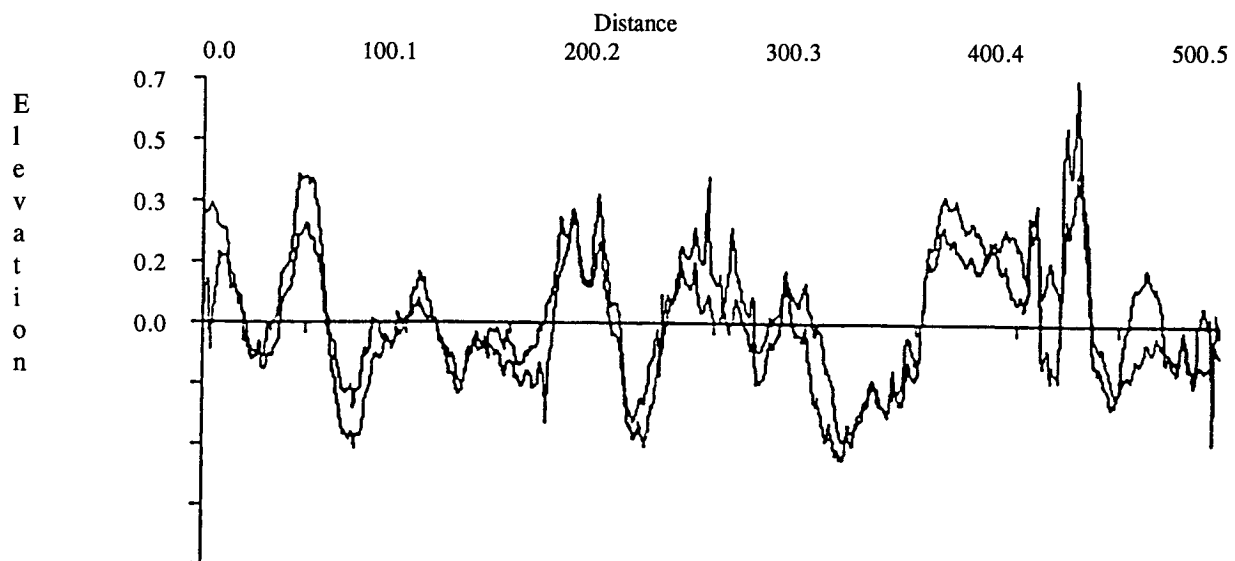
The <Plot> option is used to display the elevation data collected by the profilometer in a graphical format as shown in Figures I.2, I.3 and I.4 for a GPS, WIM and SPS site simultaneously. It can show both wheel paths of a user defined interval. The run displayed on the screen will be plotted when the plot option is chosen, at which time it is necessary to specify the following:

- i) Station Range - determines the extent of the data plotted in terms of its starting and ending station. The default values are zero and length of the site as stored in the header file.
- ii) Wheel Path - Use the space bar or enter key to include or exclude the current wheel path from the plot.
- iii) Printer - Use the space bar or enter key to check the options available. Either dot matrix or laser printers can be used. The [TAB] or arrow keys can be used to move between the options and the space bar or enter key to choose the printer type.

The following example illustrates the use of these features. Assume that a run was made over a 2000 ft long section of pavement. During the IRI analysis, a spike condition was reported at 1234 ft from the start of the run in the left wheel path. To verify this, view the



Study: GPS: E45007 Date: 30/04/1992 Run:1  
Road: US 50  
Start: End:  
Lane: LN 1 Direct.: West Bd  
From: 0.00 To: 500.50



Right WP

Left WP

PgUP = Prior

PgDn = Next ESC = quits F2 = Screen Dump

**Figure I.2. The Profile in a Graphical Format for a GPS Site**

Study: WIM: 51204W

Date: 12/12/1992 Run:1

Road: ST 265

Start:

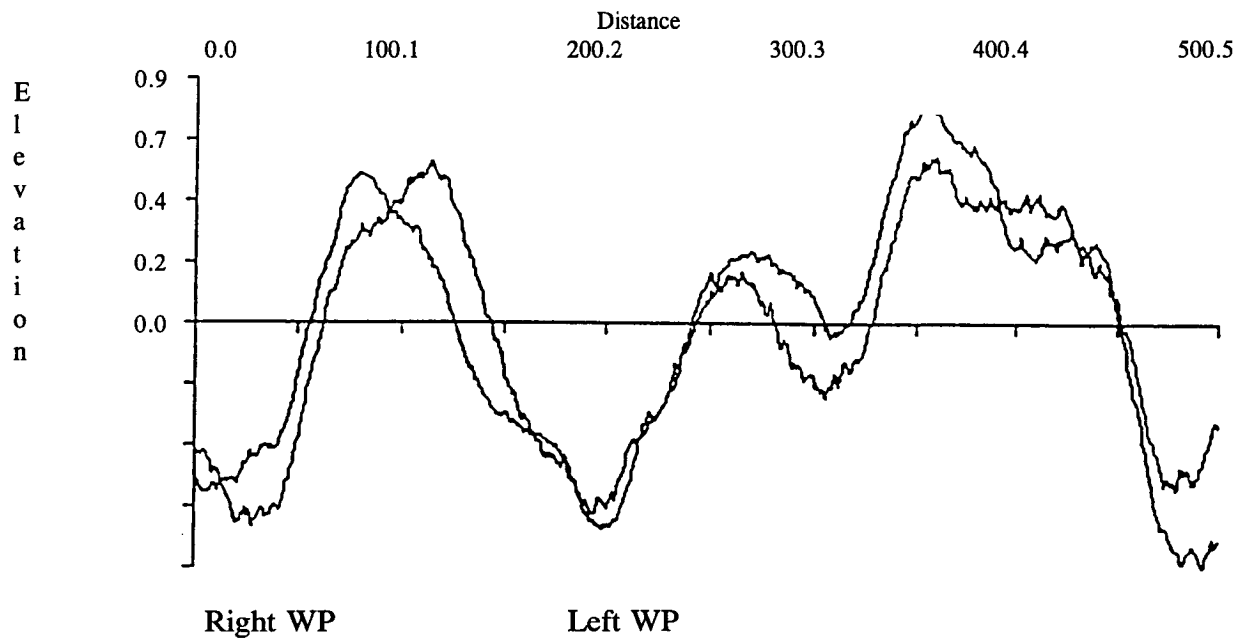
End:

Lane: LN 1

Direct.: South

From: 0.00

To: 500.50



PgUP = Prior

PgDn = Next ESC = quits F2 = Screen Dump

**Figure I.3. The Profile in a Graphical Format for a WIM Site**

Study: SPS: 87A310

Date: 24/04/1992 Run: 1

Road: HWY 400

Start:

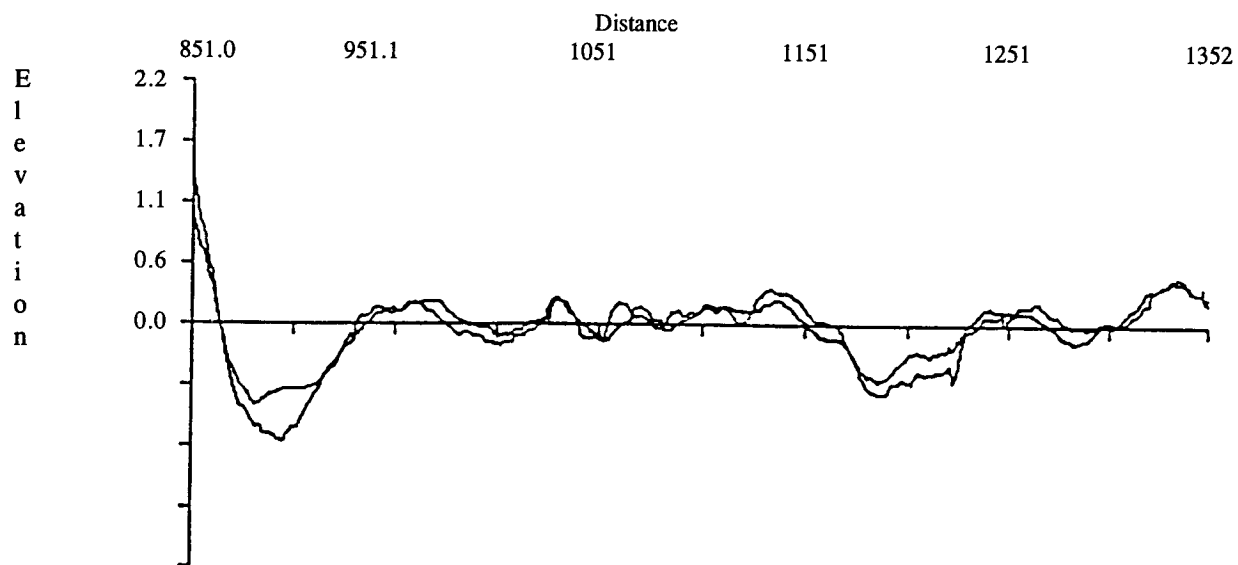
End:

Lane: LN 1

Direct.: West Bd

From: 851.00

To: 1351.50



Right WP

Left WP

PgUP = Prior

PgDn = Next ESC = quits F2 = Screen Dump

**Figure I.4. The Profile in a Graphical Format for an SPS Site**

elevations graphically by selecting a 100 ft interval, then display the data from 1200 ft - 1300 ft for the left wheel path only.

During the plot, the current wheel path can be aborted by pressing [ESC]. After the plot is completed, use [PGUP] or [PGDN] to scroll along the length of the section (assuming that a plot interval specified is less than the total length of data) or press [ESC] to quit.

The plots can be printed by using the F2 key which is the screen dump key. Press this key after all plotting is done.

Refer to Appendix II for instructions on manipulating the profilometer data.

## *1.12 Report*

The report option from the PROFSCAN menu allows the user to produce formatted reports to one of three destination devices - Screen, File or an attached Printer. Refer to Appendix II REPORT DESTINATIONS for more information.

The reports that are capable of being generated are listed below and subsequently described:

### *1.12.1 Summary*

After analyzing the profilometer runs over the section, this report will give the IRI value of the left wheel path (LWP), the right wheel path (RWP), the average IRI value of both wheel paths, the displacement for each run and then produce a statistical summary of the IRI values. A prompt exists to select an output device as well as provide an opportunity to eliminate any questionable results by instructing the program to ignore specific runs. The latter is accomplished by logically deleting [CTRL+T] the dubious run(s) on the list. On the same screen, it is possible to add a final field comment prior to producing the report. The report also indicates if any of the runs were not included in the statistics and of the possibility of spikes.

NOTE: The statistical results will always be re-calculated prior to generating the report. This is done to ensure that the user deleted runs are accounted for. If the data fails the statistical check, a message (on the screen as well as on the report) providing notification of this will be displayed.

### *1.12.2 Spike*

This report is generated during the analysis procedure and contains the location of any spike conditions that the program has detected. The spike is identified for each run at its distance from the start of the run followed by the three consecutive elevation measurements. It is suggested that this report be printed prior to viewing the elevation data graphically on the screen.

If the first five runs do not meet the criteria specified and the profilometer operator collects more data which does contain spikes, then these spikes will be appended to the previously existing spike file of the section, if it did exist. Or, if the operator repeats the analysis, then the same spikes will be appended and two sets of the spikes will exist in the file.

NOTE: The user cannot send the spike report to a file since the information is already contained in one.

### ***1.12.3 History***

The purpose of the history report is to provide the historical performance of a section's IRI. The program will track each site according to the STATE/PROVINCE, SECTION, or SUBSECTION if defined, DATE and RUN. It includes the IRI value for each run over the section along with the section's mean IRI.

Example outputs generated by the PROFSCAN software are provided in Appendix IV.

### **1.13 Adding a New SPS**

As mentioned previously, the section definition file contains a starting and ending station such that the entire length of the run is included for analysis. When only a subsection of the run is to be analyzed, the user must provide its starting and ending points. The user can edit the existing one to suit the needs or add another subsection by first typing [CTRL+N]. This will duplicate the section name and automatically include it into the analysis. It is necessary to provide a subsection name as well as its starting and ending stations relative to the beginning of the run. Repeating this step until all subsections are defined is required. To exclude a subsection from the analysis, input an N for NO in the Include? column.

Use the Scan Event Marks to locate any event markers which may assist in determining the required stations.

If an SPS section is extremely long or has long transition areas between sections, it is more advisable to collect the profile data in two groups (of SPS sections) or more. When using the same file/section name, care must be taken to set up separate directories for transfer and analysis of the data to avoid overwriting files. Another method is to give a different file/section name for the second group. If this method is used, the HISTORY file has to be edited so that a true history report can be produced.

This subsectioning method can also be utilized if more than one GPS site or a GPS and a WIM site are close to each other. In such case, one set of data can be collected over the sites and then subsectioned as required.

NOTE: All subsectioning must be done prior to proceeding with the analysis. Failure to do so will eliminate any means of subsectioning without first deleting all of the data files and starting again.

## **Appendix II.**

### **Manipulation of Menus, Windows, and Data in Profscan**

## **Appendix II: Manipulation of Menus, Windows, and Data in Profscan**

### **II.1 Menus**

This software is best used with a mouse. It utilizes a menu system for its user interface and consists of a series of related operations or procedures which are grouped into a horizontal band across the top of the screen. Further options are subsequently displayed in popup type menus. Anyone who is familiar with recent microcomputer software should be able to use the menu system without further help.

All available menu options have a hot key. This hot key will select and activate that option when it is pressed together with the [ALT] key or after hitting the [ALT] key alone. These keys are shown in yellow or, in the case of a monochrome screen, they will be underlined. After pressing the [ALT] key, menu selections can also be made by using the [ARROW] or in some instances, the [TAB] key to position the cursor highlight over the desired option and then confirming the selection by pressing the [RETURN] key.

A popup menu will automatically appear if further menu choices are available.

To unselect a menu, press the [ESC] key.

### **II.2 Windows**

A window is a portion of the computer monitor that is reserved for input and output. It is treated separately from the rest of the display screen. A window is easily identified in this software by the following characteristics:

- |         |   |
|---------|---|
| Titles  | - A character string centered across the top. |
| Borders | - A box surrounding the edges of the window.  |
| Shadow  | - A shadow is cast on the underlying screen.  |
| Control | - Symbols to zoom, size, and move the window. |

**NOTE:** Controls are only available when editing the raw measured data such as Profilometer elevations and Dipstick slopes.

When a window appears with the data/records displayed, use the following keys to manipulate the window:

- |       |                                     |
|-------|-------------------------------------|
| Move  | - [CTRL]+[F7], Arrows, [RETURN]     |
| Size  | - [CTRL]+[F8], Arrows, [RETURN]     |
| Zoom  | - [CTRL]+[F10] (toggle zoom/unzoom) |
| Cycle | - [CTRL]+[F1]                       |

Use the following keys to manipulate the data:

Toggle Delete	- [CTRL]+[T] (note the marker)
Append Record	- [CTRL]+[N]
Delete Field	- [CTRL]+[Y]
Select Field	- [CTRL]+[A]
Cut Field	- [CTRL]+[X]
Paste Field	- [CTRL]+[V]
Undo	- [CTRL]+[U]
Copy	- [CTRL]+[C]
Save and quit	- [CTRL]+[W]

## **II.3 Report Destinations**

### ***II.3.1 Screen***

Select this device to view the report immediately after it is generated. The report will be displayed on the monitor; use the [ARROW] and [PGUP/PGDN] keys to move around. When you have seen enough, press the [ESC] key to quit. The report is not saved for future access. The [ESC] key can also be used to cancel subsequent reporting if selected during the generation of a report. This is particularly useful to abort the reporting of multiple SPS sections.

### ***II.3.2 File***

Use this destination to save the report to a file on either the hard disk or floppy diskette. A window will appear in which the user can specify a directory, file name and extension. Default file names are shown; default extensions are \*.TXT. Use the <Save> option to proceed and the <Cancel> option or press [ESC] to cancel.

### ***II.3.3 Printer***

Selecting the printer will cause the report to print directly to an attached printer. Be sure that it is on-line. Note that some reports such as PROFICAL's summary require that the printer be capable of producing compressed output.

## **II.4 Archives**

### ***II.4.1 Backing Up the Data***

It is a good practice to make a backup and archive the data after completion of the analysis performed at the site. This provides a secondary security measure for data obtained with the profilometer since the original pre SHRPRA files exist elsewhere. In the case of the Dipstick®, the measurements as they were recorded in the field will also exist.

The user can use the Backup option to archive the data to floppy diskette(s) using the PK.ZIP format. PKUNZIP is used to restore the data at a later date (see below Restoring data from a



backup). After archiving, the user can remove the data from the hard disk to free up the space for subsequent data analysis.

When selecting <Data directory and Zip file>, another screen will prompt the user to choose a data directory on the hard disk and provide a \*.ZIP filename. The filename (site number plus extension \*.ZIP) may be modified as required as long as the user does not use an extension other than ZIP. For example, entering \PROF\NY as the path to the dataset and using 361008.ZIP as the archive filename will archive all files and subdirectories under the New York directory (recursively). Choose the floppy disk to which the data is to be archived. By selecting <Backup>, the program will then proceed to archive the dataset to the target floppy disk drive specified.

When the program has compressed the files, it will indicate which target archive floppy drive is chosen and will ask "Would you like to see a list of files?" on the floppy drive. By saying <No>, the backup will proceed. If <Yes> is chosen, a list of the files on that diskette will be displayed. The space used and available on the disk and the option of erasing these files and resuming the backup operation will be provided. If it is not desirable to erase these files, make a directory or change to an already existing directory on the floppy by choosing the <Directory> option, provided there is enough space available on the disk for backup files to be stored. The files will then go to this directory. The backup can also be aborted, the floppy can be changed and the procedure started again.

The backup will contain the following three (3) files:

1. Backup.\*
2. \*.ZIP
3. LASTDISK.JMB

In order to restore the data using the Restore menu all three files are necessary.

If multiple \*.ZIP files are to be stored on a disk, it is suggested that separate directories be used for each \*.ZIP file. At the completion of the backup, the files can be copied to the directory using the DOS xcopy command or any utility software.

NOTE: The standard DOS copy command will not recognize a 0 byte file (LASTDISK.JMB is a 0 byte file).

The user must label (Sitename, Date, etc.) and number each floppy disk (# of ##) accurately and keep them together for future use.

#### *II.4.2 Restoring Data from a Backup*

Place the backup floppy disk into the appropriate drive (be sure to close the gate). Select Restore from the Main menu.

Selecting <Locate archive files> will take the user to another screen that will show the

archived file with the ZIP extension. When done, the first menu will be displayed again and <Restore> has to be selected to start decompressing the files. When this is done, <Cancel> will return the user to the main menu.

## II.5 Date Files

The following data files are the minimum necessary for the profilometer software (PROFSCAN, PROFCHK and PROFCAL) to function correctly and originate directly from the Profilometer\*:

- \*.HDR - The header file
- \*.C## - The binary file transferred from the DEC PDP 1183 computer for GPS, SPS and CAL sites
- or \*.C#A - The binary file transferred from the DEC PDP 1183 computer for WIM and CAL sites

where *C* is an alpha character from *A* to *L*, *A* being an indication that the data was collected in January, *B* in February to *L* for December. The middle character is a number from 0 to 9, 0 being an indication for the year 1990, 1 for 1991, 2 for 1992 and 9 was used for 1989. The last character in the extension can be a number from 1 to 9 indicating the run number for GPS, SPS and CAL sites, or it can be an alpha character (*A*). For CAL sites *A* is used for run 10, *B* for run 11, all the way to *K* for run 20. For WIM sites, *M* is used for run 1, *N* for run 2, all the way to *U* for run 9.

The data subdirectory will initially start with the above mentioned set of files. As the user processes the data, more files will be created. These include:

- \*.SUM - Summary file to store interval data
- \*.HDD - Database version of the HDR file
- \*.DBF - Profilometer elevations in FOX format
- \*.IDX, \*.DDX, \*.SDX - Index files
- \*.LIM - Subsectioning information/limits
- \*.TXT - Default report files

These files and the \*.HDR file, excluding the \*.DBF files, will have the same name and extension for a GPS site and a WIM site with the same GPS name. These files, therefore, have to be put in separate subdirectories. The profilometer data files should be organized as suggested earlier under *Setting Up the Data - File Location*.

## **Appendix III. Technical Documentation for Profscan**

## **Appendix III: Technical Documentation for Profscan**

### **III.1 Introduction**

The K.J. Law profilometer® and Face Technologies Dipstick® were selected by SHRP to measure the longitudinal profile for the LTPP pavement sections. This was done in order to have a time stable and reproducible method for characterizing the longitudinal deformation in pavement structures. Pavement ride quality is best reproduced from profile data by using simulation models to characterize the roughness associated with pavement deformation. As part of the SHRP data four index values have been calculated from the profile data to represent ride quality. The source and methods for calculating the various indices are provided as part of this document.

### **III.2 Road Profile Analysis (Longitudinal Profile)**

The mathematical simulation included in the PROFSCAN software for analyzing profile data is the International Roughness Index (IRI). The IRI value is used to evaluate the consistency of the profile data collected by the profilometer and to monitor the performance of the SHRP/LTPP pavement sites.

#### ***III.2.1 International Roughness Index (IRI)***

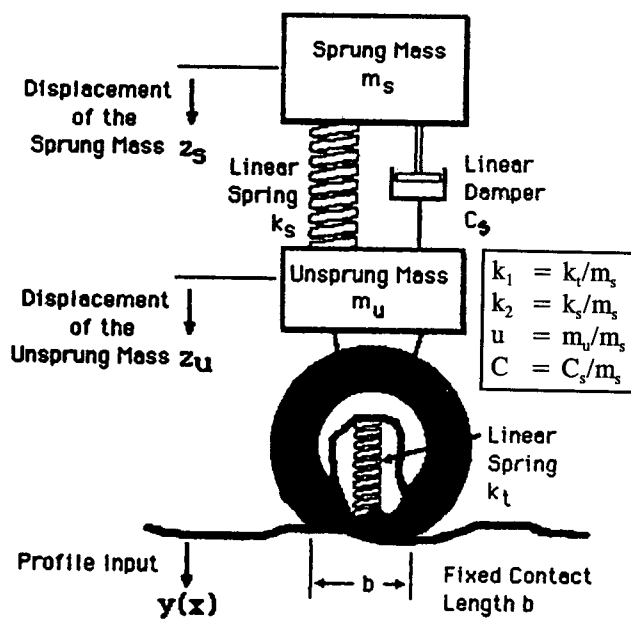
Roughness is generally characterized by a summary index that applies over a length of road. Summary index measures are obtained most directly by measuring the longitudinal profile and then applying mathematical analysis to reduce the profile to the roughness statistic. The moving average smoothing filter can be used to obtain a profile of one such standardized roughness measure: the International Roughness Index (IRI).

The International Roughness Index (IRI) was developed for the World Bank [1] as part of a continued research effort from an NCHRP Project [2]. It is the only existing roughness measure that is reproducible with a wide variety of equipment, including single and two-track profiling systems, rod and level, and response type road roughness measuring systems (RTRRMS).

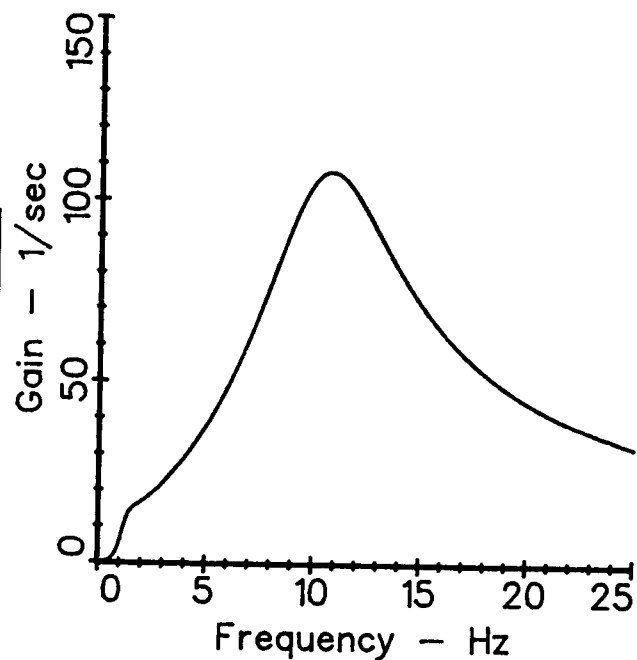
The IRI has been adopted as a standard in several countries around the world, including the United States and Canada.

#### ***III.2.2 Definition of IRI***

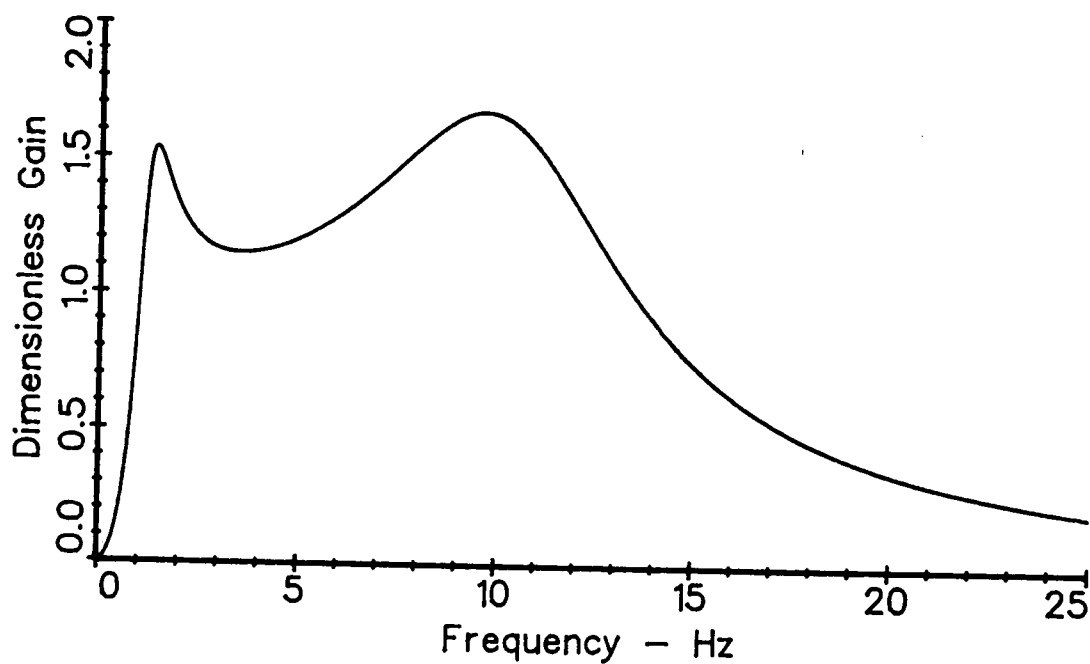
The IRI is defined as an index resulting from a mathematical simulation of vehicular response to the longitudinal profile of a pavement using a quarter-car simulation model and a traveling speed which is typically 50 mph (80 km/h). Figure III.1 illustrates the Reference Quarter Car Simulation (RQCS) concepts in terms of the mechanical model, (1a) and its frequency response (1b and 1c).



1a. Mechanical model



1b. Frequency Response of RQCS to Elevation Input



1c. Frequency Response of RQCS to Slope Input

**Figure III.1. The Quarter Car Vehicle Simulation Model**  
 (Source: World Bank Technical Paper Number 45)

The mathematic procedures involved are: 1) geometric smoothing of the profile, 2) filtering the profile signal and 3) rectifying and averaging the profile signal to yield a statistic similar to that obtained from the roadmeter in a RTRRMS. Units of IRI are either in: in./mile, m/km or mm/m (Note: 1m/km = 63.36 in./mile).

The roughness scale selected for the IRI satisfied the criteria of being time stable, transportable, relevant and readily measurable by pavement engineers anywhere in the world. It is a numeric scale that can be correlated not only to roughness measurements obtained through vehicle based profilers and RTRRMS, but also to subjective public opinions about road roughness.

The IRI scale ranges from 0 - 1000 in./mile (0 - 16 m/km) with 0 being a perfectly smooth road and 1000 being a road in almost impassible condition. Typical ranges for IRI data collected on FHWA-LTPP sites in North America would be from 50 to 300 in./mile. Pavement test sections with IRIs of 150 or less would be considered smooth and comfortable, whereas IRI values of 300 or greater would be considered rough and uncomfortable.

A typical calibration equation for RTRRMS is:

$$E(IRI) = A + B * ARS + C * ARS^2$$

where  $E(IRI)$  = expected value of roughness

$ARS$  = raw measure of average slope (Counts/km, in./mile)

$A, B, C$  = Constants based on number of calibrated sites,  $ARS$  measurements on different sites and roughness of site measured.

### *III.2.3 Computation of IRI*

The calculation of IRI is carried out by computing four variables as functions of the profile being measured. These four variables simulate the dynamic response of a reference vehicle traveling over the measured profile.

The equations for the four variables are solved for each measured elevation point except for the first. The average slope over the first 36 ft or 11m (0.5 sec at 80 kmph) is used for initializing the variables by assigning the following values:

$$Z_1' = Z_3' = (Y_a - Y_i) / 36 \quad (1)$$

$$Z_2' = Z_4' = 0 \quad (2)$$

$$a = (36 / dx) + 1 \quad (3)$$

where  $Z_1', Z_2', Z_3', Z_4'$  are the four variables,  
 $Y_a$  represents the "ath" profile elevation point,

$Y_i$  is the first point, and  
 $dx$  is the sample interval

For example, if a sample interval of  $dx = 0.5$  ft., Equation 1 would use the difference between the 73th elevation point [i.e.,  $(36/0.5) + 1$ ] and the first elevation point to establish an initial slope for computing the IRI using the profilometer data.

Then for each elevation point, from 2 to  $n$  ( $n$  = number of elevation measurements), the following four recursive equations are used.

$$Z_1 = S_{11} * Z_1' + S_{12} * Z_2' + S_{13} * Z_3' + S_{14} * Z_4' + P_1 * y' \quad (4)$$

$$Z_2 = S_{21} * Z_1' + S_{22} * Z_2' + S_{23} * Z_3' + S_{24} * Z_4' + P_2 * y' \quad (5)$$

$$Z_3 = S_{31} * Z_1' + S_{32} * Z_2' + S_{33} * Z_3' + S_{34} * Z_4' + P_3 * y' \quad (6)$$

$$Z_4 = S_{41} * Z_1' + S_{42} * Z_2' + S_{43} * Z_3' + S_{44} * Z_4' + P_4 * y' \quad (7)$$

where

$$y' = (Y_i - Y_{i-1}) / dx = \text{slope input} \quad (8)$$

$$Z_j' = Z_j \text{ from previous position } j = 1, 2, \dots, 4 \quad (9)$$

$S_{ij}, P_j$  = Coeff. that are fixed for a given sample interval,  $dx$  and a given speed

Thus equations (4 - 7) are solved for each position along the wheel track and equation (8) is used to reset the values of  $Z_1', Z_2', Z_3', Z_4'$  for the next position. Also, for each position the rectified slope (RS) of the filtered profile is computed as:

$$RS_i = |Z_3 - Z_i| \quad (10)$$

After these equations have been solved for all profile points, the IRI is calculated as

$$IRI = \frac{1}{n-1} \sum RS_i \quad (11)$$

The IRI statistic is thus the average of the rectified slope (ARS) variable over the test section.

The coefficients  $S_{ij}$  and  $P_j$  are constants that are fixed by the "time step", which is the time that would be needed by a vehicle to advance over one profile measurement interval at the simulation speed. These coefficients are computed for the sample interval of the device that collects profile data.

The reference Quarter Car Simulator includes a smoothing of the input profile using a 10 in. (250 mm) moving average. In the case of the K. J. Law Profilometer, which measures the road profile at 0.5 ft. (150 mm) intervals, an interpolation of the profile points is needed to

employ the correct base length in the moving average. The moving average is obtained as the average of the next three points over the base length of 1 ft. intervals. The IRI is then calculated by solving the equation for each average point using the appropriate coefficients ( $S_y$ ,  $P_i$ ) in Equations 4-9 for a sample interval of 0.5 ft.

The displacement from either the Dipstick or Profilometer data is calculated as:

$$\text{Disp} = \text{IRI} * (\text{dx} * n)$$

where: Disp = Displacement (in.)  
IRI = International Roughness Index (in./mile)  
 $dx$  = sample interval (mile)  
 $n$  = number of observations up to point  $i$

The World Bank has developed a computer program for estimating the IRI using metric units. This program has been modified by Pavement Management Systems Limited (PMSL) to include IRI computations in imperial units (or "standard units") for use in the SHRP-LTPP project. Figure III.2 provides the example demonstration program listings from the World Bank report. The PROFSCAN program steps, for computing IRI from profilometer and dipstick measurements, are provided in Figure III.3. Both programs have been checked using the example from the World Bank Report No. 45 [1] and the results compared favorably.

It should be noted, however, that differences have been realized when the World Bank and the programs incorporated in the PROFSCAN software are compared against the IRI produced by the Surface Dynamics software in the K.J. Law Profilometers.

The two possible explanations, at the present time, for the different results produced by the Surface Dynamics software when compared to the World Bank or PROFSCAN software are:

- (a) Differences in the method of initializing the variables;
- (b) Differences in the formulation of the vehicle simulation model and/or smoothing techniques.

In our comparison of Surface Dynamics software with the World Bank and PROFSCAN software, the major difference occurred within the first 100 ft. The Surface Dynamics software generally produced larger IRI values. This may be attributed to the dips or bumps of the core holes situated near the start of the test sections which would affect the running average of the profile data.

To summarize, the procedure for calculating the IRI using the World Bank demonstration program has been adopted by a number of agencies. The results from the PROFSCAN software compare favorably to those calculated by other agencies using the same data set. As standards and practices change, the PROFSCAN software should be easily modified and adapted.



```

1000 REM This program demonstrates the IRI computation
1010 REM
1020 REM
1030 REM -----Initialize constants
1040 DIM Y(26), Z(4), Z1(4), ST(4, 4), PR(4)
1050 READ DX
1060 K = INT(.25 / DX + .5) + 1
1070 IF K < 2 THEN K = 2
1080 BL = (K - 1) * DX
1090 FOR I = 1 TO 4
1100     FOR J = 1 TO 4
1110         READ ST(I, J)
1120     NEXT J
1130     READ PR(I)
1140 NEXT I
1150 REM -----Initialize variables
1160 INPUT "profile elevation 11 m from start:", Y(K)
1170 INPUT "X = 0 Elevation = ", Y(1)
1180 Z1(1) = (Y(K) - Y(1)) / 11
1190 Z1(2) = 0
1200 Z1(3) = Z1(1)
1210 Z1(4) = 0
1220 RS = 0
1230 IX = 1
1240 I = 0
1250 REM ----- Loop to input profile and Calculate Roughness
1260 I = I + 1
1270 PRINT "X = "; IX * DX
1280 IX = IX + 1
1290 INPUT "Elev. = "; Y(K)
1300 REM ----- Compute Slope Input
1310 IF IX < K THEN Y(IX) = Y(K)
1320 IF IX < K THEN GOTO 1270
1330 YP = (Y(K) - Y(1)) / BL
1340 FOR J = 2 TO K
1350     Y(J - 1) = Y(J)
1360 NEXT J
1370 REM -----Simulate Vehicle Response
1380 FOR J = 1 TO 4
1390     Z(J) = PR(J) * YP
1400     FOR JJ = 1 TO 4
1410         Z(J) = Z(J) + ST(J, JJ) * Z1(JJ)
1420     NEXT JJ
1430 NEXT J
1440 FOR J = 1 TO 4
1450     Z1(J) = Z(J)
1460 NEXT J
1470 RS = RS + ABS(Z(1) - Z(3))
1480 PRINT disp = "; RS * DX, "; IRI = ";RS / I"
1490 GOTO 1260
1500 END
1510 DATA 0.25
1520 DATA .9966071, .01091514, -.002083274, .0003190145, .005476107
1530 DATA -.5563044, .9438768, -.8324718, .05064701, 1.388776
1540 DATA .02153176, .002126763, .7508714, .008221888, .2275968
1550 DATA 3.335013, .3376467, -39.12762, .4347564, 35.79262

```

**Figure III.2. Demonstration Program for Computing IRI with a Microcomputer**  
*(Source: World Bank Technical Paper Number 45)*

## PROCEDURE IRICALC

```

*      -----
* Purpose: To determine IRI from profilometer elevations in the left
*          and right wheel paths
* Notes : Modified from original BASIC code obtained from the world
*          bank report.

PARAMETERS Begin, Finish
* Determine start and end records
  Startcd = IIF(Begin=0, 1, Begin*12/samint)
  Endrcd = Finish*12/samint
  DO showindo
  ACTIVATE WINDOW w_proc
  CLEAR

* Initialize some variables
  STORE 0 TO ZL,ZR,Z1L,Z1R,YL,YR,I,RSL,RSR,IX,Dist,iI,iIX,iRSL,iRSR,Intcntr

* Inform user of processing
  @ 00, 02 SAY "Section: " +          header.SECT_NO
  @ ROW(),40 SAY "Run No.: " +        STR(header.RUN_NO, 1)
  @ 01 ,02 SAY " Date: " +            DTOC(header.SVY_DATE)
  @ ROW(),36 SAY "Oper/Driver: " +    header.OP_DR
  @ 02, 02 SAY " Road: " +            header.RDESCR
  @ 03, 02 SAY " Direction: " +      header.DIR
  @ 04,02 SAY " Sample interval: " +  STR(header.INTSTOR, 2) + " (in)"
  @ 05,02 SAY "Distance Travelled: " + STR(header.DISTANCE,4) + " (ft)"
  @ 05,40 SAY "Average Speed: " +     STR(header.avgspeed,2) + " (mph)"
  @ 06,02 SAY "End comment: " +      header.END_COMT
  @ 08,02 SAY "Subsection: " +        sectn.SUBSECT
  @ ROW(),30 SAY "Station: " +

STR(sectn.START,7,1) + " to " + ;    STR(sectn.END,7,1)
  @ 09,02 SAY "Elapsed distance (ft):"
  @ 11,16 SAY "IRI (in/mi) Interval Information" COLOR BU/BG
* Determine summary intervals and display appropriate heading
  Sumint = IIF(Sumint = 0, sectn.END - sectn.START, Sumint)

  IF Sumint # header.DISTANCE
    @ 12,07 SAY "Interval"
    @ 12,20 SAY "Left WP"
    @ 12,COL()+5 SAY "Right WP"
    @ 12,COL()+5 SAY "Average"
  ELSE
    @ 12,25 SAY "None requested"
  ENDIF

  Rundist = IIF(sectn.END=0, header.DISTANCE, sectn.END - sectn.START)

* Allow the user to abort the analysis
  SET ESCAPE ON
  ON ESCAPE DO ABORT

  Iring = .T.

```

Figure III.3. PROFSCAN IRI Computation for Profilometer and Dipstick Data

SELECT ELEVS

\* Disable the logically deleted records (Spikes?)  
SET DELETED ON

GOTO Startrcd

IF Dipin  
    YL(1) = Df\_left\*25.4  
    YR(1) = Df\_right\*25.4  
ELSE  
    YL(1) = Dleft\*25.4  
    YR(1) = Dright\*25.4  
ENDIF

GOTO Startrcd + Seed

IF Dipin  
    YL(k) = Df\_left\*25.4  
    YR(k) = Df\_right\*25.4  
ELSE  
    YL(k) = Dleft\*25.4  
    YR(k) = Dright\*25.4  
ENDIF

GOTO Startrcd+1  
Z1L(1) = (YL(k)-YL(1))/11  
Z1R(1) = (YR(k)-YR(1))/11  
Z1L(3) = Z1L(1)  
Z1R(3) = Z1R(1)  
STORE 1 TO IX, iIX

\* Loop through all records for this section/subsection  
\* until: 1) user hits escape key  
\*        2) gone past the subsection's ending record  
\*        3) we've run out of data (end of file)  
DO WHILE Dist <= Rundist .AND. Iring .AND. !EOF()  
    I = I + 1  
    iI = iI + 1

\* The following code is adapted from the world banks report

DO WHILE .T.  
    IX = IX + 1  
    iIX = iIX + 1  
    Dist = IX \* samint/12  
  
    IF Dipin  
        YL(k) = Df\_left\*25.4  
        YR(k) = Df\_right\*25.4  
    ELSE  
        YL(k) = Dleft\*25.4  
        YR(k) = Dright\*25.4  
    ENDIF  
    IF IX < k

```

        YL(IX) = YL(k)
        YR(IX) = YR(k)
        SKIP
    LOOP
ELSE
    EXIT
ENDIF
ENDDO
YPL = (YL(k) - YL(1))/BL
YPR = (YR(k) - YR(1))/BL

* Check for spikes on profilometer data.
* Note: Cannot detect spikes on dipstick data slopes.
* This is not part of the world bank code.

* A spike is identified where a 'peak' is produced
* between any three consecutive elevations and whose
* magnitude is greater than or equal to the user specified
* value
IF !Dipin
    Lspik1 = ABS(YL(2)-YL(1))
    Rspik1 = ABS(YR(2)-YR(1))
    Lspik2 = ABS(YL(3)-YL(2))
    Rspik2 = ABS(YR(3)-YR(2))

    IF (Lspik1 >= Spike*25.4) .AND. (Lspik2 >= Spike*25.4/2)
        .AND.(SIGN(YL(2)-YL(1))#SIGN(YL(3)-YL(2)))
        = Sayspike("Left ", Dist, YL(1), YL(2), YL(3))
        flg = .T.
    ENDIF

    IF (Rspik1 >= Spike*25.4) .AND. (Rspik2 >= Spike*25.4/2)
        .AND.(SIGN(YR(2)-YR(1))#SIGN(YR(3)-YR(2)))
        = Sayspike("Right", Dist, YR(1), YR(2), YR(3))
        flg = .T.
    ENDIF
ENDIF

FOR J = 2 TO k
    YL(J-1) = YL(J)
    YR(J-1) = YR(J)
ENDFOR

FOR J = 1 TO 4
    ZL(J) = PR(J)*YPL
    ZR(J) = PR(J)*YPR
    FOR JJ = 1 TO 4
        ZL(J) = ZL(J)+ST(J,JJ)*Z1L(JJ)
        ZR(J) = ZR(J)+ST(J,JJ)*Z1R(JJ)
    ENDFOR
ENDFOR
FOR J = 1 TO 4
    Z1L(J) = ZL(J)
    Z1R(J) = ZR(J)

```

```

ENDFOR

RSL = RSL + ABS(ZL(1) - ZL(3))
RSR = RSR + ABS(ZR(1) - ZR(3))
DISP = (RSL+RSR)/2*mDX
LDISP = RSL*mDX
RDISP = RSR*mDX
IRIL = RSL/I * 63.36
IRIR = RSR/I * 63.36
IRIB = (RSL+RSR)/(2*I) * 63.36
iRSL = iRSL + ABS(ZL(1) - ZL(3))
iRSR = iRSR + ABS(ZR(1) - ZR(3))
iDISP = (iRSL+iRSR)/2*mDX
iIRIL = iRSL/iI * 63.36
iIRIR = iRSR/iI * 63.36
iIRIB = (iRSL+iRSR)/(2*iI) * 63.36
@ 09,25 SAY Dist PICTURE "#####.#"

IF (iIX*sumint/12 = Sumint .AND. Sumint # 0) .OR. EOF()
    Intcntr = Intcntr + 1
    @ 13,07          SAY Intcntr*Sumint PICTURE "####.#"
    @ 13,20          SAY iiril PICTURE "###.###"
    @ 13,COL() + 5 SAY iirir PICTURE "###.###"
    @ 13,COL() + 6 SAY iirib PICTURE "###.###"

    * Store the summary information in the SUMMARY dbf.
    IF Procail
        IF !SEEK(STR(speed,2)+Subsectn+STR(Intcntr*Sumint,5),'SUMMARY')
            SELECT SUMMARY
            APPEND BLANK
        ENDIF

        runiril = "summary.r" + STR(header.run_no, 1) + "_iril"

        runirir = "summary.r" + STR(header.run_no, 1) + "_irir"
        REPLACE summary.SUM_SUBSEC WITH Subsectn
        REPLACE summary.SUM_SPEED WITH speed
        REPLACE summary.SUM_INT WITH Intcntr*Sumint
        REPLACE (runiril) WITH iiril, (runirir) WITH iirir
    ELSE
        IF !SEEK(Scount + Subsectn + STR(Intcntr*Sumint,5), 'SUMMARY')
            SELECT SUMMARY
            APPEND BLANK
        ENDIF

        REPLACE ;
        summary.SUM_RUN WITH thisrun, summary.SUM_SUBSEC WITH
            Subsectn, ;
        summary.SUM_INT WITH Intcntr*Sumint, summary.SUM_IRIL WITH iiril,;
        summary.SUM_IRIR WITH iirir, summary.SUM_IRIB WITH iirib, ;
        summary.SUM_DISP WITH iDISP
    ENDIF
SELECT ELEVS

```

```

        STORE 0 TO iI, iRSL, iRSR, iIRIL, iIRIR, iIRIB, iDISP
        iIX = 1
    ENDIF

    SKIP
    ENDDO

    * Update the history file
    IF !Procal
        SELECT SITE
        LOCATE FOR CODE = VAL(SUBSTR(header.SECT_NO, 1, 2))
        SELECT HISTORY

        IF !SEEK(header.SECT_NO + STR(thisrun,1) + Subsectn +
            DTOC(header.SVY_DATE))
            APPEND BLANK
            REPLACE NAME WITH site.NAME, SECT_NO WITH
                header.SECT_NO,;
            RUN_NO WITH header.run_no, SVY_DATE WITH
                header.SVY_DATE,;
            H_SUBSECT WITH Subsectn, SPIKE_COND WITH FLG
        ENDIF

        REPLACE LEFT_IRI WITH Iril, RIGHT_IRI WITH Irir, BOTH_IRI
            WITH Irib, ;
        DISPL WITH DISP, SPIKE_COND WITH FLG
        SELECT ELEVS
    ELSE
        * Determine the statistics for PROCAL (calibration)
        IF !SEEK(STR(speed,2)+Subsectn, 'STATS')
            SELECT stats
            APPEND BLANK
            REPLACE stats.cal_speed WITH speed, stats.cal_subsec WITH Subsectn
            SELECT ELEVS
        ENDIF

        DIMENSION maxmin(4,2)
        maxmin(1,1) = -999.99 && maxleft
        maxmin(2,1) = -999.99 && maxright
        maxmin(3,1) = 999.99 && minleft
        maxmin(4,1) = 999.99 && minright
        maxmin(1,2) = 0 && maxleft chainage
        maxmin(2,2) = 0 && maxright chainage
        maxmin(3,2) = 0 && minleft chainage
        maxmin(4,2) = 0 && minright chainage

        * Statistics for dipstick data
        IF Dipin
            SCAN
            * Maximum left wp
            IF DF_LEFT > maxmin(1,1)
                maxmin(1,1) = DF_LEFT
                maxmin(1,2) = RECNO()*IIF(samint=6, 0.5, 1)
            ENDIF
        ENDIF
    ENDIF

```

```

* Maximum right wp
IF DF_RIGHT > maxmin(2,1)
    maxmin(2,1) = DF_RIGHT
    maxmin(2,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF

* Minimum left wp
IF DF_LEFT < maxmin(3,1)
    maxmin(3,1) = DF_LEFT
    maxmin(3,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF

* Minimum right wp
IF DF_RIGHT < maxmin(4,1)
    maxmin(4,1) = DF_RIGHT
    maxmin(4,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF
ENDSCAN
ELSE
* Statistics for Profilometer data
SCAN
* Maximum left wp

IF DLEFT > maxmin(1,1)
    maxmin(1,1) = DLEFT
    maxmin(1,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF

* Maximum right wp
IF DRIGHT > maxmin(2,1)
    maxmin(2,1) = DRIGHT
    maxmin(2,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF

* Minimum left wp
IF DLEFT < maxmin(3,1)
    maxmin(3,1) = DLEFT
    maxmin(3,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF

* Minimum right wp
IF DRIGHT < maxmin(4,1)
    maxmin(4,1) = DRIGHT
    maxmin(4,2) = RECNO()*IIF(samint=6, 0.5, 1)
ENDIF
ENDSCAN
ENDIF
DO CASE
CASE BETWEEN(count, 1, 5)
    Scount = STR(count, 1)
CASE BETWEEN(count, 6, 10)
    Scount = STR(count-5, 1)
CASE BETWEEN(count, 11, 15)

```

```

        Scount = STR(count-10, 1)
    CASE BETWEEN(count, 16, 20)
        Scount = STR(count-15, 1)
    ENDCASE
    statl      = "stats.r"+STR(VAL(Scount),1)+"_iril"
    statr      = "stats.r"+STR(VAL(Scount),1)+"_irir"
    statb      = "stats.r"+STR(VAL(Scount),1)+"_irib"
    minell     = "stats.r"+STR(VAL(Scount),1)+"_minelel"
    maxell     = "stats.r"+STR(VAL(Scount),1)+"_maxelel"
    minelr     = "stats.r"+STR(VAL(Scount),1)+"_mineler"
    maxelr     = "stats.r"+STR(VAL(Scount),1)+"_maxeler"
    minlol     = "stats.r"+STR(VAL(Scount),1)+"_minlocl"
    maxlol     = "stats.r"+STR(VAL(Scount),1)+"_maxlocl"
    minlor     = "stats.r"+STR(VAL(Scount),1)+"_minlocl"
    maxlor     = "stats.r"+STR(VAL(Scount),1)+"_maxlocl"
    disl       = "stats.r"+STR(VAL(Scount),1)+"_displ"
    disr       = "stats.r"+STR(VAL(Scount),1)+"_dispr"

    * Update the statistics dbf.
    SELECT STATS
    REPLACE (statl) WITH Iiril, (statr) WITH Irir, (statb) WITH Irib, ;
    (disl) WITH ldisp, (disr) WITH rdisp, (minell) WITH maxmin(3,1), ;
    (maxell) WITH maxmin(1,1), (minelr) WITH maxmin(4,1), ;
    (maxelr) WITH maxmin(2,1), (minlol) WITH maxmin(3,2), ;
    (maxlol) WITH maxmin(1,2), (minlor) WITH maxmin(4,2), ;
    (maxlor) WITH maxmin(2,2)
    ENDIF

    RELEASE maxmin
    RELEASE WINDOW w_proc
    WAIT CLEAR
    SET DELETED OFF
    ON ESCAPE
    SET ESCAPE OFF
    RETURN

```



## References

1. Sayers, M.W., Gillespie, T.D., and Queiroz, C.A.V., "The International Road Roughness Experiment: Establishing Correlation and a Standard for Measurement", World Bank Technical Report No. 45, Washington, D.C., 1986.
2. Gillespie, T. D., Sayers, M. W., and Segel, L., "NCHRP Report No. 228: Calibration of Response Type Road Roughness Measuring Systems", TRB, National Research Council, Washington, D.C., 1980, 88 pp.

## **Appendix IV. Results of Profscan Software**

# PROFSCAN SUMMARY REPORT

Friday, May 21, 1993

10:18:55

## SETUP:

Spatial Filter Wavelength.. 300.0                      Speed... 48.20 (mph)  
 Start Method..... PHOTOCELL  
 Stop Method.....  
 Wavelength Initialization.. DISABLED

## SURVEY:

GPS ..... 545007  
 Oper/Driver.. BASEL/SCOTT  
 Date..... 30/04/1992  
 Time..... 14:13:20  
 Station..... 0 - 500

## LOCATION:

Begin.....  
 End.....  
 Lane..... LN 1  
 Direction.. WEST BD  
 Horizontal  
 Offset...

## CONDITIONS:

### Pavement

Road..... US 50  
 Surface Mat'l. P-CC  
 Surface Cond.. POOR

### Weather

Temperature... 60 F  
 Cloud..... OVERCAST  
 Other..... PRE OVERLAY TESTING

RUN #	----- IRI (in/mi) -----		DISPLACEMENT (in)	INCLUDE IN STAT	POSSIBLE SPIKES
	LEFT	RIGHT			
1	140.10	189.16	164.63	Yes	No
2	139.76	185.56 (L)	162.66	Yes	Yes (*)
3	140.09	186.06	163.07	Yes	No
4	140.50 (H)	190.25 (H)	165.37 (H)	Yes	Yes (*)
5	139.35 (L)	185.95	162.65 (L)	Yes	Yes (*)

Minimum	139.35		162.65
Maximum		190.25	165.37
Mean + 1 %	141.35	189.26	165.31
Mean	139.96	187.40	163.68
Mean - 1 %	138.56	185.52	162.03
Std. Deviation	0.38	1.92	1.12
2 % of Mean	2.79	3.74	3.27
Coef. of Vari.	0.2	1.0	0.6

YOU HAVE SUFFICIENT RUNS

- (\*) - See file 545007.SPI for details
- (L) - Lowest value.
- (H) - Highest value.

## REMARKS

GPS Run	545007 Comments
1	End of run RUN OK Final Field no 11 or sats, some potholes in rwp, preoverlay patches RCO
2	End of run RUN OK Final Field no 11 or sats, some potholes in rwp, preoverlay patches RCO
3	End of run RUN OK Final Field no 11 or sats, some potholes in rwp, preoverlay patches RCO
4	End of run RUN OK Final Field no 11 or sats, some potholes in rwp, preoverlay patches RCO
5	End of run RUN OK Final Field no 11 or sats, some potholes in rwp, preoverlay patches RCO
6	End of run Final Field RCO
7	End of run Final Field RCO
8	End of run Final Field RCO
9	End of run Final Field RCO

## SETUP:

Spatial Filter Wavelength.. 300.0  
 Start Method..... PHOTOCCELL  
 Stop Method.....  
 Wavelength Initialization.. DISABLED

Speed... 48.70 (mph)

## SURVEY:

WIM ..... 371993W  
 Oper/Driver.. SCOTT/DOUG  
 Date..... 13/12/1992  
 Time..... 11:39:43  
 Station..... 0 - 500

## LOCATION:

Begin.....  
 End.....  
 Lane..... LN 1  
 Direction.. NORTH  
 Horizontal  
 Offset...

## CONDITIONS:

## Pavement

Road..... ST 421  
 Surface Mat'l. A-CC  
 Surface Cond.. NEW

## Weather

Temperature... 55 F  
 Cloud..... CLEAR  
 Other.....

RUN #	IRI (in/mi)			DISPLACEMENT (in)	INCLUDE IN STAT	POSSIBLE SPIKES
	LEFT	RIGHT	BOTH			
1	122.68	148.12	135.40	12.82	Yes	Yes (*)
2	130.74	152.65	141.70	13.42	No	Yes (*)
3	120.73 (L)	154.75 (H)	137.74	13.04	Yes	Yes (*)
4	132.82 (H)	146.00	139.41 (H)	13.20	Yes	Yes (*)
5	122.42	144.22 (L)	133.32 (L)	12.63	Yes	Yes (*)
6	127.75	145.11	136.43	12.92	Yes	Yes (*)

Minimum	120.73		133.32
Maximum		154.75	139.41
Mean + 1 %	126.53	149.11	137.82
Mean	125.28	147.64	136.46
Mean - 1 %	124.02	146.16	135.09
Std. Deviation	4.44	3.78	2.07
2 % of Mean	2.50	2.95	2.72
Coef. of Vari.	3.5	2.5	1.5

YOU HAVE SUFFICIENT RUNS

- (\*) - See file 371993.SPI for details  
 (L) - Lowest value.  
 (H) - Highest value.

WIM Run	371993W Comments
1	End of run Final Field RUNS OK RCO
2	End of run RUN OK Final Field RUNS OK RCO
3	End of run RUN OK Final Field RUNS OK RCO
4	End of run RUN OK Final Field RUNS OK RCO
5	End of run RUN OK Final Field RUNS OK RCO
6	End of run RUN OK Final Field RUNS OK RCO
7	End of run Final Field RCO
8	End of run Final Field RCO
9	End of run Final Field RCO

# PROFSCAN SUMMARY REPORT

Wednesday, May 26, 1993

09:47:23

## SETUP:

Spatial Filter Wavelength.. 300.0                      Speed... 46.90 (mph)  
 Start Method..... PHOTOCELL  
 Stop Method.....  
 Wavelength Initialization.. DISABLED

## SURVEY:

SPS            ..... 87A311  
 Oper/Driver.. SCOTT/RANDY  
 Date..... 24/04/1992  
 Time..... 11:56:25  
 Station..... 4,855 - 5,355

## LOCATION:

Begin.....  
 End.....  
 Lane..... LN 1  
 Direction.. SOUTH  
 Horizontal  
 Offset...

## CONDITIONS:

### Pavement

Road..... HWY 400  
 Surface Mat'l. A-CC  
 Surface Cond.. POOR

### Weather

Temperature... 60 F  
 Cloud..... PCLOUDY  
 Other.....

RUN #	----- IRI (in/mi) -----		DISPLACEMENT (in)	INCLUDE IN STAT	POSSIBLE SPIKES
	LEFT	RIGHT      BOTH			
1	92.35	107.48 (H)	99.92	Yes	No
2	95.73	107.21	101.47 (H)	Yes	No
3	91.51 (L)	107.19	99.35	Yes	No
4	94.79	104.65	99.72	Yes	No
5	94.44	102.89	98.67 (L)	Yes	No
6	93.32	105.68	99.50	Yes	No
7	100.60 (H)	99.33 (L)	99.97	Yes	No
8	94.78	106.98	100.88	Yes	No
9	95.68	102.11	98.89	Yes	No

Minimum	91.51		98.67
Maximum		107.48	101.47
Mean + 1 %	95.74	105.88	100.81
Mean	94.80	104.84	99.82
Mean - 1 %	93.85	103.78	98.82
Std. Deviation	2.46	2.69	0.84
2 % of Mean	1.89	2.09	1.99
Coef. of Vari.	2.5	2.5	0.8

YOU HAVE SUFFICIENT RUNS

(L) - Lowest value.  
 (H) - Highest value.

## REMARKS

SPS Run	87A311 Comments
1	End of run RUN OK, SOME SAT RT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
2	End of run RUN OK, SOME SAT RT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
3	End of run RUN OK, SOME SAT RT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
4	End of run RUN OK, SOME SAT RT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
5	End of run RUN OK, SOME SAT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
6	End of run RUN OK, SOME SAT RT ON SS Final Field good testing conditions, sat left on stripes RCO
7	End of run SAT ON STRIPES, BOTH SENSORS Final Field good testing conditions, sat left on stripes RCO
8	End of run RUN OK, SAT LEFT ON STRIPES Final Field good testing conditions, sat left on stripes RCO
9	End of run RUN OK, SAT LEFT ON STRIPES Final Field good testing conditions, sat left on stripes RCO



C:\PROF\WV\GPS\RD4\545007.SPI

Survey Date:30/04/1992

The following runs could contain possible 'spike' conditions:

GPS: E45007

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
2	Right	500.0	-0.10	-0.23	-0.17

GPS: E45007

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
4	Right	498.0	-0.10	-0.25	-0.18

GPS: E45007

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
5	Right	249.5	0.24	0.35	0.30

C:\PROF\NC\WIM\371993.SPI

Survey Date:13/12/1992

The following runs could contain possible 'spike' conditions:

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
M Left		311.5	0.00	0.43	0.29

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
N Left		311.5	0.41	0.62	0.08
N Left		312.5	0.08	-0.10	0.26
N Left		313.0	-0.10	0.26	0.15

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
O Left		310.5	-0.05	0.37	0.30

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
P Left		310.5	-0.05	0.51	0.40

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
Q Left		310.5	0.06	-0.05	0.26
Q Left		311.5	0.26	0.42	0.00

WIM:371993W

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
R Left		310.5	-0.01	0.35	0.26

C:\PROF\ONSPS\RD4\87B300.SPI

Survey Date:20/08/1992

The following runs could contain possible 'spike' conditions:

SPS: 87B340

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
1 Left		17.0	-0.62	-0.72	-0.65

SPS: 87B340

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
2 Left		486.5	-0.36	-0.48	-0.43

SPS: 87B340

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
3 Left		242.0	0.03	-0.07	-0.00

SPS: 87B320

Run	WP	Dist'n	Elev.1	Elev.2	Elev.3
5 Left		25.0	-0.51	-0.62	-0.55

STATE/PROVINCE NAME: WEST VIRGINIA

GPS NUMBER: 545007

DATE SURVEYED	RUN NO.	IRI	RMSVA		MO	SLOPE VARIANCE
			4'	16'		
14/11/1989	1	142.57				
	2	145.86				
	3	145.13				
	4	142.36				
	5	143.00				
Section mean:		143.78				
20/09/1990	1	152.52				
	5	156.11				
	6	157.31				
	7	154.34				
	8	155.86				
Section mean:		155.22				
25/06/1991	2	158.62				
	3	160.03				
	4	158.87				
	5	161.58				
	6	160.94				
Section mean:		160.00				
15/11/1991	1	150.42				
	2	151.62				
	3	149.33				
	4	145.77				
	5	149.17				
Section mean:		149.26				
30/04/1992	1	164.63				
	2	162.66				
	3	163.07				
	4	165.37				
	5	162.65				
Section mean:		163.67				

SHRP - LTPP  
NARCO - PMS

PROFILOMETER DATA COLLECTION  
AND PROCESSING SUMMARY

STATE/PROVINCE NAME: NORTH CAROLINA

WIM NUMBER: 371993W

DATE SURVEYED	RUN NO.	IRI	RMSVA		MO	SLOPE VARIANCE
			4'	16'		
13/12/1992	1	135.40				
	3	137.74				
	4	139.41				
	5	133.32				
	6	136.43				
Section mean:		136.46				

SHRP - LTPP  
NARCO - PMS

PROFILOMETER DATA COLLECTION  
AND PROCESSING SUMMARY

STATE/PROVINCE NAME: ONTARIO

SPS NUMBER: 87A311

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DATE SURVEYED	RUN NO.	IRI	RMSVA		MO	SLOPE VARIANCE
			4'	16'		
24/04/1992	1	99.92				
	2	101.47				
	3	99.35				
	4	99.72				
	5	98.67				
	6	99.50				
	7	99.97				
	8	100.88				
	9	98.89				
Section mean:		99.81				

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## **Appendix V. Forms for the K.J. Law Profilometer**

## Daily Check List

Day: \_\_\_\_\_ Month: \_\_\_\_\_ Year: \_\_\_\_\_ Signature: \_\_\_\_\_

Item	Checked	Comment
Under Hood		
Fluids		
Engine Oil		
Brake		
Windshield Wiper Fluid		
Radiator Coolant		
Transmission		
Drive Belt Tension		
Water Pump		
Alternator		
A/C Compressor		
Battery Cable Connection (tight, clean)		
General Appearance		
Leaks		
Cracked Hoses		
Cracked Insulation		
Loose Nuts & Bolts		
Generator		
Oil		
Choke/Breather		
Muffler/Exhaust		
Exterior		
Lights		
Front		



Item	Checked	Comment
Rear		
Emergency		
Turning Signals		
Beacon		
Flashers		
Arrow Board		
Glass Cleaning		
Windshield		
Mirror Lights		
Light Sensor		
Receiver		
Photo Cell Box		
Body (clean)		
Underbody		
Tires Properly Inflated		
Fluid Leaks		
Shroud		
Exhaust		
Interior		
Remove trash and organize the interior in preparation for the day's work.		
Air Conditioner/Heater		
Temperature Range		
Storage Area		
Clean		

## SHRP-LTPP Major Maintenance/Repair Activity Report

Region: \_\_\_\_\_ Date: \_\_\_\_\_

Equipment ID

Make: \_\_\_\_\_ Model: \_\_\_\_\_ S/N: \_\_\_\_\_

Odometer: \_\_\_\_\_ (where applicable)

Reason for Maintenance Work (Choose only one):

Scheduled: \_\_\_\_\_ Not Scheduled: \_\_\_\_\_ Routine: \_\_\_\_\_

Description of Maintenance and Reason: \_\_\_\_\_

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Agency Performing Maintenance: \_\_\_\_\_ Cost: \_\_\_\_\_

Name: \_\_\_\_\_

Street: \_\_\_\_\_

City: \_\_\_\_\_ State: \_\_\_\_\_ Zip: \_\_\_\_\_

Phone Number: \_\_\_\_\_

Contact Name: \_\_\_\_\_

Date In: \_\_\_\_\_

Date Out: \_\_\_\_\_

**SHRP Profilometer Maintenance Data**  
**Gasoline**

S.N. \_\_\_\_\_  
Region \_\_\_\_\_  
Crew \_\_\_\_\_

Conversion  
1 US Gal = 3.78 SL

Automobile Gasoline Record, Month of: \_\_\_\_\_

Date	Odometer	No. Gals.	Amount
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
TOTAL			

## Profilometer Calibration Log

Date: \_\_\_\_\_

Profilometer Operator: \_\_\_\_\_

Calibration Test	Old Scale Factor (A)	Computer New Scale Factor (B)	% Error in Scale Factor $B-A/B \times 100$	Need to Change Y or N	New Scale Factor	Field Calibration Y or N
Right Displacement Sensor						
Left Displacement Sensor						
Accelerometers						
Distance Measuring Instrument						

If % Error in Scale Factor of a displacement sensor or accelerometer is not between  $-1$  or  $1$ , then place a "Y" in the "Need to Change" column; otherwise, place "N".

If % Error in Scale Factor for Distance Measuring Instrument is not between  $-0.47$  and  $0.47$ , then place a "Y" in the "Need to Change" column; otherwise, place "N".

## SHRP-LTPP Profilometer Field Activity Report

SHRP Region: \_\_\_\_\_ SHRP Assigned ID: \_\_\_\_\_ File Name: \_\_\_\_\_

State: \_\_\_\_\_ Testing: \_\_\_\_\_ District: \_\_\_\_\_

LTPP Experiment Code: \_\_\_\_\_ Route/Highway Number: \_\_\_\_\_

Testing Date: \_\_\_\_\_ Sheet Number: \_\_\_\_\_

Profilometer Vehicle Before Operation Checks: \_\_\_\_\_ (initial)

	Time	Odometer
Start Travel	_____	_____
End Travel	_____	_____
Ready to Test	_____	_____
Begin Testing	_____	_____
End Testing	_____	_____
Start Travel	_____	_____
End Travel	_____	_____

Down Time: \_\_\_\_\_ Hours Reasons: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Number of Tests	IRI Reading
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____
9	_____
10	_____
11	_____
12	_____
13	_____
14	_____
15	_____

Additional Remarks Regarding Testing: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Profile Crew: Driver: \_\_\_\_\_ Operator: \_\_\_\_\_

Others Present (list names and agencies) \_\_\_\_\_  
\_\_\_\_\_

## SHRP-LTPP Profilometer Field Activity Report—SPS

SHRP Region: \_\_\_\_\_

State: \_\_\_\_\_

SPS Section: \_\_\_\_\_

Number of Sections Used in Profilometer Runs: \_\_\_\_\_

File Name: \_\_\_\_\_

Stations: \_\_\_\_\_

SHRP ID: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

File Name: \_\_\_\_\_

Stations: \_\_\_\_\_

SHRP ID: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

File Name: \_\_\_\_\_

Stations: \_\_\_\_\_

SHRP ID: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

[illegible]

## **Appendix VI. Forms for Dipstick Measurements**



**MANUAL DIPSTICK DATA COLLECTION FORM**  
(Longitudinal Profile)

TEST SITE: _____ DATE: _____ WEATHER: _____ OPERATOR: _____ RECORDER: _____ DIPSTICK SERIAL NUMBER: _____ START TIME: _____ STOP TIME: _____ WHEELPATH: _____											
Distance (ft)	Elevations (in.)		Distance (ft)	Elevations (in.)		Distance (ft)	Elevations (in.)		Distance (ft)	Elevations (in.)	
	Pass 1	Pass 2		Pass 1	Pass 2		Pass 1	Pass 2		Pass 1	Pass 2
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		
<b>TOTAL</b>											
COMMENTS: _____ _____ _____											

DATE: \_\_\_\_\_ STATE CODE: \_\_\_\_\_  
 OPERATOR: \_\_\_\_\_ SHRP SECTION I.D.: \_\_\_\_\_  
 RECORDER: \_\_\_\_\_  
 DIPSTICK SERIAL NUMBER: \_\_\_\_\_

LOCATION	DIPSTICK READING															TOTAL	SUM
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
0+00																	
0+50 (15 m)																	
1+00 (30 m)																	
1+50 (45 m)																	
2+00 (60 m)																	
2+50 (75 m)																	
3+00 (90 m)																	
3+50 (105 m)																	
4+00 (120 m)																	
4+50 (135 m)																	
5+00 (150 m)																	

# DIPSTICK FIELD ACTIVITY REPORT

SHRP REGION \_\_\_\_\_ STATE CODE \_\_\_\_\_ SHRP ASSIGNED ID \_\_\_\_\_  
 STATE \_\_\_\_\_ TESTING \_\_\_\_\_ DISTRICT \_\_\_\_\_  
 LTPP EXPERIMENT CODE \_\_\_\_\_ ROUTE/HIGHWAY NUMBER \_\_\_\_\_  
 EQUIPMENT SERIAL NUMBER \_\_\_\_\_  
 TESTING DATE \_\_\_\_\_ SHEET NUMBER \_\_\_\_\_  
 WEATHER \_\_\_\_\_

=====

DIPSTICK PRE-OPERATION CHECKS \_\_\_\_\_ (initials)

TIME

READY TO TEST \_\_\_\_\_  
 BEGIN TESTING \_\_\_\_\_  
 END TESTING \_\_\_\_\_  
 START TRAVEL \_\_\_\_\_  
 END TRAVEL \_\_\_\_\_

DOWN TIME \_\_\_\_\_ HOURS

REASONS \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

ADDITIONAL REMARKS

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

DIPSTICK PROFILE CREW  
 NAMES: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

TRAFFIC CONTROL CREW  
 NAMES: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

COPIES: RCOC

FORM F01/SEPT 1990

SHRP MAJOR MAINTENANCE/REPAIR ACTIVITY REPORT

REGION \_\_\_\_\_ DATE \_\_\_\_\_

EQUIPMENT ID \_\_\_\_\_

MAKE: FACE CONSTRUCTION TECHNOLOGY, INC. MODEL: \_\_\_\_\_

SERIAL NUMBER: \_\_\_\_\_

REASON FOR MAINTENANCE WORK (CHOOSE ONE ONLY)

SCHEDULED \_\_\_\_\_ NONSCHEDULED \_\_\_\_\_

DESCRIPTION OF MAINTENANCE AND REASON:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

AGENCY PERFORMING MAINTENANCE

COST: \_\_\_\_\_

NAME: \_\_\_\_\_

STREET ADDRESS: \_\_\_\_\_

CITY: \_\_\_\_\_

PHONE NUMBER: \_\_\_\_\_

CONTACT NAME: \_\_\_\_\_

DATE IN: \_\_\_\_\_

DATE OUT: \_\_\_\_\_

COPIES TO: RCOC, LTPP DIVISION

FORM F02/DEC 1992

ZERO CHECK

First Reading\_\_\_\_\_

Rotate 180 degrees

Second Reading\_\_\_\_\_

Total, if within  $\pm 0.001$  proceed or else adjust the start end pin as suggested in the manual and repeat the zero check.

CALIBRATION CHECK

First Reading\_\_\_\_\_

Place calibration block

Second Reading\_\_\_\_\_ -  $0.125 = \text{First Reading}$   
 $\pm 0.003$  proceed or else  
contact FACE through RCO

## **Appendix VII. Form for Rod and Level Measurements**

# Rod and Level Data Collection Form

Sheet Number: \_\_\_\_\_  
 Site: \_\_\_\_\_ Route: \_\_\_\_\_  
 Date: \_\_\_\_\_ Weather: \_\_\_\_\_  
 Wheelpath: \_\_\_\_\_ Level Operator: \_\_\_\_\_  
 Recorder: \_\_\_\_\_ Rod Person: \_\_\_\_\_  
 Type and Model of Level: \_\_\_\_\_  
 Start Time: \_\_\_\_\_ Stop Time: \_\_\_\_\_

Distance (ft.)	I.S.	B.S.	F.S.	Distance (ft.)	I.S.	B.S.	F.S.	Distance (ft.)	I.S.	B.S.	F.S.
0				34				67			
1				35				68			
2				36				69			
3				37				70			
4				38				71			
5				39				72			
6				40				73			
7				41				74			
8				42				75			
9				43				76			
10				44				77			
11				45				78			
12				46				79			
13				47				80			
14				48				81			
15				49				82			
16				50				83			
17				51				84			
18				52				85			
19				53				86			
20				54				87			
21				55				88			
22				56				89			
23				57				90			
24				58				91			
25				59				92			
26				60				93			
27				61				94			
28				62				95			
29				63				96			
30				64				97			
31				65				98			
32				66				99			
33				67				100			

I.S. = Intermediate Sight; B.S. = Backsight; F.S. = Foresight

Comments: \_\_\_\_\_

## Glossary

ACC	Asphalt Cement Concrete
ASCII	American Standard Code for Information Interchange
Data Base	A collection of logically related <u>records</u> or <u>files</u> . A data base consolidates information that was previously stored in separate files, and allows them to be used for many applications. The data base may also include any ancillary files to the data base files such as index, report and query files.
DIP	Digital Incremental Profiler
Directory	A summary of all files on a disk, analogous to a table of contents.
DOS	Disk Operating System. DOS is often used as a shortened form of PC-DOS or MS-DOS, an operating system designed for the 8086 family of microprocessors.
EGA	Enhanced Graphic Adapter
Field	A single piece of information; the smallest unit manipulated in a data base. <u>Records</u> consist of one or more fields.
File	A collection of related data. The information within a data base file is stored as individual records.
GPS	General Pavement Studies
Hang Up	A non programmed stop in a routine usually unforeseen or unwanted. The computer system does not respond to inputs made by the user, and no other activity seems to be taking place. The solution to this problem would be to <u>reboot</u> the system.
IBM	International Business Machines
Index File	A file which allows records in a data base to be ordered alphabetically, chronologically, or numerically.
IRI	International Roughness Index.
LTPP	Long Term Pavement Performance
LWP	Left Wheel Path
Menu	A list of options preserved by a computer program.
MO	Mays Output
MS	Microsoft
NIMS	National Information Management Data base System. The central data base of the LTPP program, located at the Transportation Research Board, Washington, DC.
PC	Personal Computer



<b>PMSL</b>	<b>Pavement Management Systems Limited</b>
<b>PROFCAL</b>	<b>Profilometer Calibration Software</b>
<b>PROFCHK</b>	<b>Profilometer Checking and Analysis Software</b>
<b>PROFSCAN</b>	<b>Profilometer Scanning Software</b>
<b>PROQUAL</b>	<b>Profile Quality Assurance and Analysis Software</b>
<b>RAM</b>	<b>Random Access Memory</b>
<b>RCO</b>	<b>Regional Coordination Office</b>
<b>Reboot</b>	<b>The procedure executed by the computer when the power is switched off and on (cold boot) or when the combination of CTRL-ALT-DEL keys are pressed (warm boot).</b>
<b>Record</b>	<b>A body of information treated as a set within a data base.</b>
<b>RIMS</b>	<b>Regional Information Management Data base System. The regional data bases that contribute data to the <u>NIMS</u>.</b>
<b>RMSVA</b>	<b>Root Mean Square Vertical Acceleration</b>
<b>RWP</b>	<b>Right Wheel Path</b>
<b>Section</b>	<b>A portion of roadway that is homogeneous in nature (the entire section is of similar properties in terms of pavement structure, traffic levels and history). See also <u>site</u>.</b>
<b>SHRP</b>	<b>Strategic Highway Research Program</b>
<b>Site</b>	<b>The location of test sections for the evaluation of variables in pavement construction and rehabilitation over a 20- year period.</b>
<b>Spike</b>	<b>Rapid change in elevation</b>
<b>SPS</b>	<b>Specific Pavement Studies</b>
<b>SV</b>	<b>Slope Variance</b>
<b>VGA</b>	<b>Video Graphic Adapter</b>
<b>WIM</b>	<b>Weigh In Motion</b>